ESSAYS ON INTERACTION OF MULTILATERAL ENVIRONMENTAL AGREEMENTS AND INTERNATIONAL TRADE

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ESSAYS ON INTERACTION OF MULTILATERAL ENVIRONMENTAL AGREEMENTS AND INTERNATIONAL TRADE

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To FangFang, TangTang and DanDan

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SUMMARY

This thesis studies the interaction between environmental regulations/agreements and international bilateral trade performance. The pollution haven hypothesis states that stringent environmental policies may drive the dirty industries to the countries with less stringent regulations. This paper verifies the pollution haven hypothesis from three different aspects, international trade flow and foreign direct investment flow changes caused by the European Union Emission Trading Scheme and the general effects of all types of environmental regulations on country level bilateral trade flows.

In this thesis, I investigate and verify pollution haven hypothesis with panel regressions with industry and country level data. I show that imports will increase for European Union Emission Trading Scheme (EU ETS) members for dirty industries while exports decrease. The changed pattern for two way trade flows follows the Environmental Kuznet Curve. Also, EU ETS changes firms' foreign direct investment decisions. According to my theoretical model, both inward and outward foreign direct investment on dirty industries decrease for EU ETS members. This result is confirmed by an empirical study with panel data. Under uniform distribution of freely allocated allowances, efficient firms are driven out of the market. In the last chapter, I show a more general conclusion that the presence of any type of multilateral environmental agreement decreases bilateral trade.

CHAPTER I

INTRODUCTION

It is well known that there is a U-shaped bilateral relationship between pollution per capita and income, called the environmental Kuznet Curve. One possible explanation for this relationship is given by the Pollution Haven Hypothesis. The pollution haven hypothesis, or pollution haven effect, is the idea that polluting industries will relocate to jurisdictions with less stringent environmental regulations. From the point of view of firms and industries stringent environmental regulations are considered a threat to their international competitiveness because pollution abatement significantly increases production costs. According to Michael Greenstone (2002, JPE), in the first 15 years in which the Clean Air Act was in force (1972-87), nonattainment counties (relative to attainment ones) lost approximately 590,000 jobs, 37 billion in capital stock, and 75 billion (1987 dollars) of output in pollution-intensive industries. According to international trade theories, comparative advantage and the Hecksher-Ohilin-Vanek (HOV) model, the strictness of environmental regulations is related to the exports of polluting industries. Second, besides the trade pattern shifts, the structure of industries could be also affected since the pollution-intensive industries will be forced to relocate to less strictly regulated regions. Extensive industrial migration to foreign countries can cause unemployment and undermine the balance of trade. Moreover, free trade agreements that may improve the mobility of capital can accelerate this trend.

In the past few decades, many countries recognized the importance of environmental protection. Various environmental regulations have been adopted in order to limit the emission of pollutants and to protect the ecology and species. The concern related to the pollution haven hypothesis is that governments will engage in inefficient competition to attract polluting industries by weakening their environmental standards. A welfare-maximizing government should set standards so that the benefits justify the costs at the margin. Jurisdictions have different assimilative capacities, costs of abatement, and values regarding the environment. So heterogeneity in pollution standards is to be expected, and by extension industry migration to less stringent jurisdictions does not necessarily raise efficiency concerns. Another concern is that trade liberalization might lead to a "rate to the bottom" in standards as countries weaken their environmental policy in response to the competitive pressures of freer trade (Copleland and Taylor, 2004).

Thus, in this thesis, I investigate pollution haven hypothesis from all three aspects mentioned above. In the first chapter, how the environmental regulations, in particular, European Union Emission Trading Scheme affects bilateral trade flows for regulated industries. My empirical results shows significant effect of a pollution haven generated by European Union Emission Trading Scheme (EU ETS). The inflow trade volumes increase and the outflow decreases in member countries. The second chapter studies the other possible consequence of pollution haven, the change in foreign direct investment (FDI) as a result of newly introduced environmental policy with a theoretical model considering both trade flows and FDI flows. Different from previous two chapter, in order to learn how the presences of all kinds of environmental agreements interacting with multilateral trade agreements. Instead of a focus on a single environmental agreement, I include all types of multilateral environmental agreements under different subjects to investigate the effects of international environmental agreements with free trade agreements simultaneously.

In the first two chapters, I investigate the pollution haven generated by EU ETS. There are several reasons for investigating the EUETS. The most important reason is the crucial ecology problem caused by global climate change. Global warming caused by the emissions of greenhouse gas, has been studied broadly since the end of the last century. Gradually increasing global temperatures have the potential to harm entire ecological systems. Aiming to slow down global warming, the United Nations Framework Convention on Climate Change (UNFCCC) announced the Kyoto Protocol in 1995 and it entered into force in 2005. Led by the Kyoto Protocol, EU ETS was established in 2005. Operated by the European Commission, it is the largest emissions trading scheme in the world. It is proceeding until 2020 and is adjusted according to its performance, including emission goals and changes in industrial structures as the system evolves. How and whether those proposed adjustments will be conducted depends on the influence and effectiveness of the current policy. The second reason of picking EU ETS is the special properties of global pollutants. The restrictions on carbon emissions may lead to carbon leakage and free riders. Carbon leakage and free rider could weaken the benefit to the environment though the cost remains the same. Hence, looking for a balance between the regulation and international competitiveness is much more important for global pollutants. The third reason is the multinational trading scheme of EU ETS. It seems that the trading scheme with initial allocation as a lump sum transfer. It should have no distortion effects on firms' behavior even with uneven initial allocations. Thus, the effects of EU ETS on international trade flows and FDI decisions are not clear.

If pollution haven hypothesis holds, we could expect that countries' comparative advantage changes as a result of abatement cost of environmental regulations. The regulated countries may import more "dirty industry goods" from unregulated countries while export less. Or on the other side, regulated countries may have their dirty industries relocated to foreign countries without or with less stringent environmental regulations. To study this effect, my thesis starts with the effects on bilateral trade flows in the first chapter. I show that EU ETS impedes regulated industries in international competition by decreasing exports and increasing imports. This result confirmed the pollution haven hypothesis of EU ETS.

The second chapter focuses more on foreign direct investment (FDI). FDI, which has been shown as a substitution for bilateral trade (Markusen 2002), also has an important role in international competition. Given the intra-industry trade flows change, how firms' FDI decisions change after the implementation of EU ETS is an important issue to further verify the pollution haven hypothesis. According to Xing and Kolstad (2000), if environmental regulations generate distortions in the operation of polluting industries, the multinational enterprise may initially respond with the intra-firm transfer of its production facility, or it may increase the investment in its subsidiaries located in the country with lenient regulation. These adjustments plus relocation of entire plants will change FDI flows. Moreover, since EU ETS is a relatively new launched regulation scheme, firms may not be able to make relocation decisions in the short run. Thus, FDI is a great indicator to test the pollution haven hypothesis.

The third part of my thesis focuses on the presence of international environmental agreements. Different from the previous two chapters and current literature that focus on a single environmental agreement or regulation, my data covers all types of environmental agreements, including pollution regulations on air and marine, species, natural resources and habitant protections and energy. The importance of studying ex- and post- effects lies on the self-selections of the member countries. It seems that signing multilateral environmental agreements (MEAs) with international trade partners could eliminate the disadvantage in international competitions caused by stringent environmental regulations. Voluntary participation on MEAs is similar to trade liberalization realized by free trade agreements (FTA). The most widely used model to study the ex post effects of trade related policies is gravity equation. According to Baier and Bergstrand (2007) "the gravity equation is typically used to explain cross-sectional variation in country pairs' trade flows in term of the countries' incomes, bilateral distance, and dummy variables for common languages, for common land borders, and for the presence of absences of an FTA." However, researchers believe that participation of environmental and trade agreements are endogenous and also determined by some unobserved heteroskedasticity of bilateral countries. Thus, an OLS regression could be biased. In this chapter, I adopt several methods and adjustment on cross-sectional gravity equations as well as panel regressions treated with various fixed effects.

My thesis distinguishes from the current literature in several perspectives. In the first two chapters, unlike most of the early research which focuses on local pollutants, I study the pollution haven effect caused by EU ETS, a cross country regulation focusing on a global pollutant, carbon dioxide. The efficiency of an environmental policy requires that the benefit to the environment equals the cost of regulation. Additionally, the effect of EU ETS is a two-sided sword, since it could either benefit the regulated industries or impede them depending on the allocated pollution allowance. EU ETS is a long-term adjustable environmental regulation. Understanding the effect of current policies is necessary for further improvement. To deal with the endogeneity of the amount of freely allocated allowances, I apply moments of heteroscedasticity to instrument freely allocated allowances (Lewbel, 2012) in my study. When I investigate the FDI flow changes, rather than focusing only on FDI, my model consists of both FDI and international trade flows that are taken as substitutes. The inclusion of both could give a clearer understanding of the effect of EU ETS and whether it generates a pollution haven effect or not. In order to explain how the flows change and substitute for each other, the endogenous determination of the number of firms, firms' efficiency, and entry and exit are introduced into the model as well.

The third chapter[1] begins to generate a more general conclusion about pollution haven. In order to obtain a complimentary data, I use International Environmental

[1]This chapter is co-worked with Dr. Tibor Besedes, Xinping Tian, and Jianqiu Wang.

Agreements (IEA) Database Project by Ronald B. Mitchell and the IEA Database Project, 2002-2014. This truly systematic, comprehensive and up to date list of multilateral environmental agreements (MEAs) include not only the agreements that counter the pollution but also the agreements that aim to preserve the ecology and species. Another contribution of this part is to solve the possible endogeneity. In addition, our data keep a track for the total numbers of MEAs, MEAs with different subjects or with the same lineage. Our date could provide us more a detailed estimation for the effects of MEAs on international trade flows in future studies.

In general, my thesis proves the existence of pollution haven generated by environmental policies (regulation, agreements or protocol). I find evidence that environmental policies decrease bilateral trade flows as well as FDI flows. The first chapter shows for total trade flows that the effect of EU ETS increases EU imports and decreases EU exports, indicating that EU ETS has caused a deterioration in EU's comparative advantage. In particular, those countries in short positions suffer more from EU ETS. For some industries in which there are excessive allocations, such as glasses, pottery and ceramics, the total effects of EU ETS is to increase imports while decrease exports. It provides us a political suggestion that further emission cuts could be applied on them. The amount of freely allocated allowances shift trade flows significantly, and their directions are predictable. Thus, the social planner could adjust firms' emissions and productions through controlling their free allocated allowance.

The second indicator of pollution haven – FDI also decreases after EU ETS. My theoretical model suggests that both inward and outward FDI flows decrease after EU ETS. But these empirical results are statistically insignificant. The theoretical model suggests that output for regulated firms is lower than that of unregulated firms given the same productivity. If two different regulated firms are under a uniform freely allocated allowances scheme, the more efficient one is more likely to exit the market. It is plausible that EU ETS will not only decrease FDI inward flows because of the higher cost of regulation, but also decreases FDI outward flows because efficient firms are driven out of the market.

The general evaluation of environmental agreements also indicates the pollution haven hypothesis holding. There are significant negative effects on imports of MEAs and positive effects on imports of free trade agreements (FTAs). Those effects are consistent with various model setting (including year fixed effect, country fixed effect, reporter by partner fixed effect etc.). Also, traditional estimates of the MEAs on international trade flows by using cross-section gravity equation is biased. It overestimated the negative effect of MEAs. Another important finding in our work is that the simultaneous absence of FTAs and MEAs increases the bilateral international trade a lot and significantly. This result could be well explained by the self-selection of FTAs and MEAs.

CHAPTER II

TESTING THE POLLUTION HAVEN HYPOTHESIS: EVIDENCE FROM EUROPEAN UNION EMISSIONS TRADING SCHEME

2.1 Introduction

One of the most important global climate changes, global warming caused by the emissions of greenhouse gas has been studied broadly since the end of last century. Gradually increasing global temperatures have the potential to harm entire ecological systems. Aiming to slow down global warming, the United Nations Framework Convention on Climate Change (UNFCCC) adopted the Kyoto Protocol in 1995 which entered into force in 2005. Led by the Kyoto Protocol, European Union Emissions Trading Scheme (EU ETS) was established in 2005. Operated by the European Commission, it is the largest emission trading scheme in the world. It is proceeding until 2020 and is adjusted according to its performance, including emission goals and changes in industrial structures as the system evolves. How and whether those proposed adjustments will be conducted depends on the influence and effectiveness of the current policy.

Generally speaking, EU ETS, like other environmental regulations, generates both benefits of decrease of emissions and also costs for conducting them. Those effects could be reflected in international trade. On one side, as a stringent environmental regulation, EU ETS could impede regulated industries in international competition. This outcome follows naturally from the pollution haven hypothesis which claims that pollution control costs are important enough to measurably influence trade and investment. The Heckscher-Ohlin-Samuelson model provides theoretical foundation for this perspective. Since relative factor endowments associated with pollution control costs change in regulated countries, the production of pollution-intensive goods may shift to other countries without emission regulations.

On the other side, EU ETS is a cap-and-trade scheme with its major allowances freely allocated from its launching point until now. The comparative advantage of industries that have abundant emission permits and lower abatement costs may increase. Because of those inverse effects, the real influence of current EU ETS policies on international trade is unclear.

In this chapter I investigate in which direction and by how much the EU ETS shifts the member countries' international trade by using bilateral trade data. Recently researchers have focused on EU ETS itself, that is, how the trading scheme affects the efficiency of the policy. Convincing evidence of pollution haven hypothesis based on a global pollutant has not been found, nor has it been fully investigated.

Hintermann (2009) considers the EU ETS impact on the allowance price, finding evidence that prices were not initially driven by marginal abatement costs. Neuhoffa et al. (2006) studied how the allocation allowances affect the electricity sector only. Bruyn et al., (2008) by studying the resulting competitive change examine the pollution haven effect of EU ETS using data on Dutch industries. They found that there is an increase in costs as well as a change in the ratios of export to the total value of domestic production.[1] The limitation of their study is their assumption that EU ETS is under a full auction scenario in which all allowances are auctioned to producers. However, most allowances so far have been given away freely.

There are several differences between my work in this chapter and the current literature. First, unlike most of the early research which focuses on local pollutants,[2] I

[1]In this paper, they investigate the cost and export ratio changes separately for each industry. For example, the aluminium firms face an increase of cost by 5%, the export ratio changed by 76%.

[2]The toxicity index for the local pollutants depends on the damage to the air, like sulfur dioxide, poisoned substance to the soil and water. Generally, regulation in one country is less likely to affect the environment in another country, not considering boundary, wind and precipitation.

study the pollution haven effect caused by EU ETS, a cross country regulation focusing on a global pollutant, carbon dioxide. The efficiency of an environmental policy requires that the benefit to the environment equals the cost of regulation. But for a global pollutant, possible carbon leakage could weaken the benefit to the environment though the cost remains the same. Moreover, decreasing the greenhouse gas globally could generate free-riders as well. Hence, the balance between the regulation and international competitiveness is much more important for global pollutants.

Additionally, the effect of EU ETS is a two-sided sword, since it could either benefit the regulated industries or restrict them depending on the allocated allowance. As a long-term adjustable environmental regulation, understanding the effect of current policies is necessary for their further improvement. Second, this chapter uses a new panel dataset from 2000 to 2011 that combines detailed regulation data with bilateral international trade flows, by carefully matching the industry specific allocated allowance with the 2- or 3-digit SITC classification of trade flows. The analysis is based on the gravity equation. It is well known that the gravity equation may suffer from endogeneity when evaluating the effect of trade-relevant policies. In this chapter, I uses fixed effects to capture each country's characteristics and considering the uniform standard and enforcement of EU ETS for each. Besides the panel data regression, I also use the difference-in-difference method.

The plausible endogeneity of the quantity of allocated allowances is controlled with instruments. Since the national allocation plans which determine the detailed allocated allowances for each industry also take international trade into account, this chapter applies moments of heteroscedasticity to instrument for freely allocated allowances (Lewbel, 2012). This is quite different from the majority of literature that uses abatement costs to measure the environmental policies and deal with endogeneity.

Empirical results in this chapter suggest several importation policy implications. As for total trade flows, the pure effect of EU ETS is to increase EU imports and decrease EU exports,, indicating that EU ETS has cause a deterioration in EU's comparative advantage. I look into the trade flows by separating them into intra EU and extra EU trade. The effects for EU and non EU countries have the same trend in imports and exports. The effect on the non EU country is slightly larger comparing to EU countries. However, due to the larger flows within EU, the pooled regression coefficients are much closer to intra EU results. Member countries whose allocated allowances are not enough for production, or whose net emission trade flows are negative (in short position) do face a larger disadvantage in international competition.

These results suggest that there is a pollution haven effect caused by the EU ETS. However, the shift is only within the EU. In particular, those countries in short positions suffer more from EU ETS. As most reports indicated, there is excessive allocation for several industries such as glasses, pottery and ceramics. The total effect of EU ETS on them is to increase imports while decreasing exports. Thus, further emission cuts should be laid on them. The amount of freely allocated allowances shift trade flows significantly, and their directions are predictable. Thus, the social planner could adjust firms' emissions and productions through controlling their free allocated allowance.

This chapter is outlined as follows. In section II, I give a short description of the current literature on the pollution haven hypothesis. In section III, I describe EU ETS and its possible outcomes in detail. In sections IV and V, the dataset and methodologies are introduced respectively. In section VI, I discuss the results. Section VII offers robustness checks. The conclusion follows in section VIII.

2.2 Literature Review

There are numerous studies of the role of environmental regulations on the pattern of trade, both theoretical and empirical. Siebert (1977), Pethig (1976) and McGuire

(1982) provide the possible background for pollution haven hypothesis by studying a two-goods open economy. They all conclude that the environmental policy will increase social welfare if marginal social costs of production are higher than the marginal utility of consumption. The comparative advantage model implies that a country will have a production advantage if it has abundant resources.

However, in terms of empirical evidence, researchers have not reached an agreement on whether environmental policy affects trade. Copeland and Taylor (2004) group empirical studies into pre-1997 and post-1997. The early research mainly relied on cross-sectional data, while the later one uses panel data methods to deal with possible endogeneity problems. The most widely cited empirical work is Tobey (1990) in which two methods are used to test the hypothesis that the strictness of environmental regulations is related to exports of polluting industries. His work fails to find evidence that domestic environmental regulation has a significant impact on exports of polluting industries. Only one of the twelve included factor endowments is significant in three commodity groups. Van Beers and Van Den Bergh (2001) find no significant effect of environmental policy on exports of dirty goods for resource-intensive industries using a gravity model. Their result suffers from an endogeneity problem because of their cross-sectional dataset of 21 OECD countries in a single year only.

Controlling for endogeneity and heterogeneity using a two-stage least squares approach, Wilson, Otsuli and Sewadeh (2002) examine whether environmental regulations affect exports of dirty goods in 24 countries from 1994 to 1998. They do find some evidence that there is some tradeoff between stringent environmental regulations and trade expansion for some industries. Ederington and Minier (2003) use the environmental abatement cost as the measurement of the stringiness of regulations and treat it as endogenous in the U.S. from 1978 to 1992. They find the impact of regulation on the net trade flow is significantly high. Levinson and Taylor (2008) develop a theoretical model and test it empirically to examine the effect of environmental regulations on trade flows between the U.S., Canada, and Mexico, for 130 manufacturing industries from 1977 to 1986 and that industries hardest hit by regulations experienced the largest increases in net imports. Their main contribution is to deal with the endogeneity for foreign unobserved regulations by applying instrumental variables which are generated by weighted state characteristics.

One study that focuses on EU environmental regulations is Cavea and Blomquistb (2011). They apply the Toxic Release Inventory (TRI) index as a measure of pollution to test the pollution haven that is generated by signing of the Maastricht Treaty in 1993 on EU imports at the 2-digit SITC level from 1970 to 1999. They find no significant increase in the amount of EU toxic-intensive trade with poorer countries, although there is some increase in EU imports of toxic goods from poorer OECD and non-EU European countries, however, this result is not robust. My chapter studies the subsequent years, from 2000 to 2011 and tests the pollution haven hypothesis generated by EU ETS for a global pollutant.

2.3 European Union Emission Trading System

EU ETS is the first large emission trading scheme in the world encompassing 27 EU countries plus Iceland, Norway, and Liechtenstein and covering more than 10,000 installations with a net heat excess of 20 MW in energy and industrial sectors, which are collectively responsible for half of the EUs emissions of carbon dioxide. It was launched on January, 1, 2005 as an outcome of the Kyoto Protocol. There are three phases of EU ETS. Phase I ran from January, 1, 2005 to 31st December, 2007 and covered only carbon dioxide emissions from energy activities (combustion installations with a rated thermal input exceeding 20MW, mineral oil refineries, coke ovens), production and processing of ferrous metals, mineral industry (cement clinker, glass and ceramic bricks) and pulp, paper and board activities. Phase II ran from January, 1, 2008 to December, 31, 2012. During this period, EU ETS includes revised monitoring and reporting rules, more stringent emissions caps and additional combustion sources. New industries were included, with airlines industry being added at the beginning of 2012. Phase III started on 1st January 2013 and will go until December, 31, 2020. This period will bring major changes, such as harmonized allocation methodologies and inclusion of additional greenhouse gases and emission sources. EU ETS will be expanded to include petrochemicals, ammonia and aluminum industries and additional gases in 2013. The cap will be cut by as much as 20% compared to Phase II.

The distribution of emission allowances also differs across phases. Phase I is based on historical emissions and installation levels.[3] Phase II retains Phase I methodology but also includes several other options, such as option 2 based on historic output/capacity ratio; option 3 based on benchmarking; option 4 based on installation-level projections using any metric (emissions, input, output); and option 5 based on the marginal abatement cost. The choice of which option to apply rests with each member state. There is another significant difference in Phase III in that as much as 50% of allowances will be auctioned rather than given away. In the previous two phases only a small amount of allowances were distributed via auction, 5% and 10% in Phase I and Phase II respectively.

For each EU ETS phase, the total quantity of allowance to be allocated by each Member State is defined in the Member State National Allocation Plan (NAP) (equivalent to its UNFCCC-defined carbon account.) The European Commission has oversight of the NAP process and decides if the NAP fulfills the 12 criteria set out in

[3]The detailed methods for different sectors are varied. For example, the combustion installations are equal their 2002 direct emissions multiply projected output growth rate between 2002 and the first phase then multiply by change in energy per unit output required target between 2002 and the first phase. Also, those values are also adjusted by the possible growth rate.

Annex III of the Emission Trading Directive (EU 2003/87/EC). The first and foremost criterion is that the proposed total quantity is in line with a Member States Kyoto target.

The main participants in the allocation process are the European Commission, the member state governments, and firms that were to be included in the scheme and would be the main recipients of allowances. The role of these participants varies according to the two main issues to be decided: the 'macro' decision concerning the total number of allowances to be created by each member state, and the micro decision concerning how this total would be allocated to affected firms in each member state. Each member state took the initiative in proposing in its National Allocation Plan (NAP) total and in specifying the allocation to installations, but both aspects were subject to review by the commission. The allocation of the shortage to the EU15 resulted from the structure of the member-state commitments under the Kyoto Protocol.

In each trading period, the large emitters obtain trading permits from the NAPs and purchase EU and international trading credits as well. Each member state allocates allowances to each industrial sector. Since the electricity utility sector does not face severe non-EU international competition, most EU15 countries allocated the shortage to the power sector. The power plants account for a large amount of carbon emissions and face the largest regulation constraints, which could be uneven among EU countries. This potential difference is one reason why I focus on within-EU trade flow changes before going to the international carbon leakage effects.[4]

The price of the permission per ton of carbon is determined by the market demand and supply. The trading price is equal across the EU. Excessive allowances will result in a low carbon price, and reduced emission abatement efforts (Newbery,

[4]Carbon leakage occurs when there is an increase in carbon dioxide emissions in one country as a result of an emissions reduction by a second country with a strict climate policy.

2009). Too few allowances will result in too high a carbon price (Hepburn, 2006, p. 239). Since most of the allowances are currently given away freely, it could be viewed as endowments for each member country. Because of the mechanism of allocation and possible leakage, emissions increase in countries or sectors that have weaker regulation; there is a potential pollution haven effect since the permits are distributed and traded among countries, even though the trade price is the same across the EU. It is possible that, within EU countries, there are countries with more stringent regulations that attained fewer quotas compared to what they could have attained, and weaker regulated countries that possess more quotas.

One traditional way of environmental regulation is to add taxes on emitted pollutants. Similarly, a cap-trade scheme with purchased permission also raises the cost through increases of abatement costs. However, the possible outcomes of EU ETS are not clear. The freely allocated allowance is viewed as a windfall asset for manufacturers, and the comparative advantage for those who have abundant emission quotas will increase. Additionally, some countries have a very small proportion of allowances sold through auctions rather than given freely. Though the amount is limited, less than 5% in the first phase, and 10% in the second phase, they could have entirely opposite effects compared to the freely allocated allowances.

The possibilities could be summarized in three main points: First, launching of EU ETS is a strict environmental policy which could result in a disadvantage in international competition. Even if there is no shortage for other industries, 64% of companies responding to an October 2008 survey said they had average annual costs of monitoring and reporting of £26,000 and average annual verification costs of £9,000. Second, some industries claim that the allocation is a windfall financial asset which could benefit their international competitiveness because in Phase I and Phase II, most allowances are given away freely. Regions will export goods that use locally abundant factors. That is, countries in the long-position may export more goods that emit more CO_2 within the European Union. Third, carbon leakage may occur. External EU trading partners, not constrained by EU ETS, could have larger emissions of carbon by producing more than before due to their comparative advantage.

2.4 Theoretical Background

It seems that EU ETS distributes lump-sum allowances to countries and industries. The lump-sum payment should generate no distortion on firms' behavior. However, considering the uneven spread of EU ETS on different countries and industries as well as the change in amount of freely allocations, the payment definitely affects firm or country's competitive in the international market. The model presented in this chapter provides a basic clue regarding on how the amount of freely allocated allowances affects monopoly firms' behavior, thus affecting international trade flows as well.

Assume there are two countries, called North and South. North is regulated with a cap-and-trade environmental policy while South is not. North produces two kinds of goods, x and y. x is Cournot competed with South (duopoly in the international market) while y is a monopoly in the international market. Both goods are regulated by the environmental policy so I generate a partial equilibrium under the situation. The demand functions for goods x and y are:

$$P_x = a - bQ_x^N - \delta Q_x^S$$

$$P_y = d - cQ_y$$

The production function in each country follows Taylor and Copeland (2004):

$$Q_j^i = A_j^i L_i^j (1 - \theta_i),\ with\ i \in S, N\ and\ j \in x, y,\ \theta_i = 0\ for\ i = S$$

θ_x and θ_y stand for the effort input on abatement, labor inputs are shown in L_x^N, L_y and L_x^S, and A stands for the technology term of each country. In this model, I assume that the social planner in North will distribute the emission allocation before firms make production decisions. The freely allocated allowance is z_x and z_y. Firms could trade their allocations freely and with no costs. The price of permission is determined by the market. The effort of abatement is given as θ_i for each firm and known by the government. $\phi(1-\theta_i)Q_i^N$ is the final emissions of firm i. Thus, the profit function for each producer in both countries is:

$$\Pi_x^N = Q_x^N P_x - w_N L_x^N - P * (\phi(1-\theta_x)Q_x^N - z_x)$$

$$\Pi_y^N = Q_y^N P_y - w_N L_y^N - P * (\phi(1-\theta_y)Q_y^N - z_y)$$

$$\Pi_x^S = Q_x^N P_x - w_S L_x^S$$

Utility function for a representative consumer in country North follows a Cobb-Douglas function and their income is composed of labor income only. Goods are sold in the international market and consumers are price takers. Emissions from both countries generate negative utility.

$$U = x^\alpha y^{1-\alpha} - H(E_x^N + E_y^N + E_x^S)$$

$$s.t.\ P_x x + P_y y \leq w_N(L_x^N + L_y^N)$$

The demand of product x and product y in the domestic country is:

$$Q_x = \frac{1}{P_x}\alpha w_N[\frac{Q_x^N}{A_x^N(1-\theta_x)} + \frac{Q_y^N}{A_y^N(1-\theta_y)}]$$

$$Q_y = \frac{1}{P_y}(1-\alpha) w_N[\frac{Q_x^N}{A_x^N(1-\theta_x)} + \frac{Q_y^N}{A_y^N(1-\theta_y)}]$$

The social planner's utility is an electoral model, which is in terms of profits of firm x and y, and utility of consumers. The social planner will choose freely allocated allowances for each firm to maximize its electoral function.

$$\max_{z_x, z_y}\ s_1\Pi_x^N + s_2\Pi_y^N + U$$

Combining with the market clearing condition of emissions $E_x^N + E_y^N = z_x + z_y$, I solve the firms' decision given freely allocated allowance known, they are functions of those parameters:

$$P = P(A_x^N, A_x^N, A_x^S, \theta_y, \theta_x, w_s, w_n, a, \delta, b, d, c, z_x, z_y)$$

$$Q_x^N = Q(A_x^N, A_x^N, A_x^S, \theta_y, \theta_x, w_s, w_n, a, \delta, b, d, c, z_x, z_y)$$

$$Q_y^N = Q(A_x^N, A_x^N, A_x^S, \theta_y, \theta_x, w_s, w_n, a, \delta, b, d, c, z_x, z_y)$$

$$Q_x^S = Q(A_x^N, A_x^N, A_x^S, \theta_y, \theta_x, w_s, w_n, a, \delta, b, d, c, z_x, z_y)$$

By taking the FOCs of the government electoral function, I have:

$$\begin{aligned}
\frac{\partial G}{\partial z_x} &= s_1[\frac{\partial \pi_x^N}{\partial Q_x^S}\frac{\partial Q_x^S}{\partial z_x} + \frac{\partial \pi_x^N}{\partial P}\frac{\partial P}{\partial z_x}] \\
&+ s_2\frac{\partial \pi_y^N}{\partial P}\frac{\partial P}{\partial z_x} \\
&- H' - H'\frac{\partial Q_x^N}{\partial z_x} \\
&+ \frac{\partial U}{\partial Q_x}[\frac{\partial Q_x}{\partial Q_x^N}\frac{\partial Q_x^N}{\partial z_x} + \frac{\partial Q_x}{\partial Q_y^N}\frac{\partial Q_y^N}{\partial z_x} + \frac{\partial Q_x}{\partial p_x}\frac{\partial p_x}{\partial z_x}] \\
&+ \frac{\partial U}{\partial Q_y}[\frac{\partial Q_y}{\partial Q_x^N}\frac{\partial Q_x^N}{\partial z_x} + \frac{\partial Q_y}{\partial Q_y^N}\frac{\partial Q_y^N}{\partial z_x} + \frac{\partial Q_y}{\partial p_y}\frac{\partial p_y}{\partial z_x}]
\end{aligned} \tag{1}$$

Overall, the optimal allocations for each firm depend on its competitiveness in international market. The competitiveness depends on the firms' characteristics and stringency of environmental regulations. Since I would like to evaluate environmental regulation in industry level, especially when comparing international trade flow changes before and after EU ETS, environmental regulation is considered as a treatment, while all firms' characteristics in each industry and country could be controlled by fixed effects.

2.5 Data and Summary Statistics

Data contain export and import values for regulated sectors, gravity characteristics, and EU ETS allowances from 2000 to 2011 for EU ETS participants.

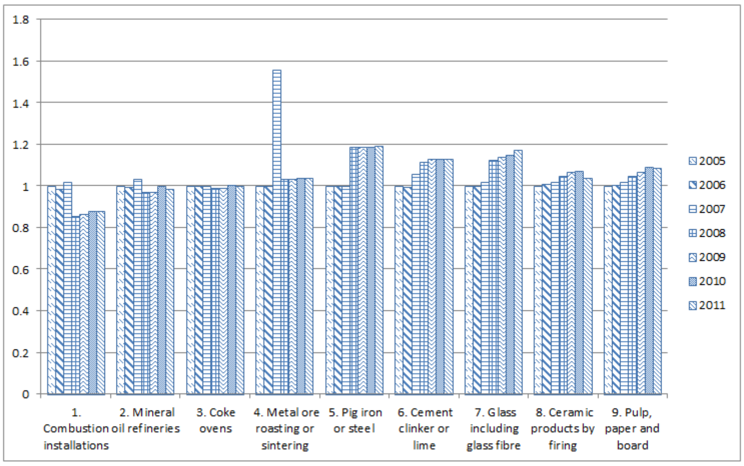
This is an unbalanced panel dataset including more than 100,000 observations for both exports and imports. The allowance data are available from the Community International Transaction Log, version 11 (CITL v.11) provided by the European Environmental Agency (EEA). The data include ten sectors: combustion installations; mineral oil refineries; coke ovens; metal ore roasting sincerity; pig iron or steel; cement clinker or lime; glass including glass fiber; ceramic products by finery; pulp, paper and board and other activities which opted in. The last sector, "other activities opted i" was included to cover other installations opted in under Article 24 of the EU ETS Directive. In practice, the activity of an installation which is listed under this sector in the CITL is often not clear. Thus, I only focus on the nine sectors which are clearly defined. The amount of allowances for each sector is shown in Figure 1. The combustion installations take most of the total freely allocated allowances and experienced reductions in Phase II. Compared to this sector, other eight sectors have a relatively constant amount of allowances[5].

There are two categories for allocation data, one is freely allocated EU allowances (EUAs) and the other one is verified emissions. Information on verified emissions and freely allocated EUAs is presented for two different scopes: "Verified emissions (all installations)" and "Verified emissions (installations with emissions for 2008 until 2011);" "Freely allocated EUAs" and "Freely allocated EUAs (installations with emissions for 2008 until 2011)."

The freely allocated EUAs measure the amount of free allocation received, but do

[5]The outlier for metal ore roasting or sintering sector in 2007 is because there were several more countries participating EU ETS in this sector since 2007 while the early members' allowances were not adjusted to fit the cap. Starting from 2008, the first year of Phase II, all allocated allowances were adjusted.

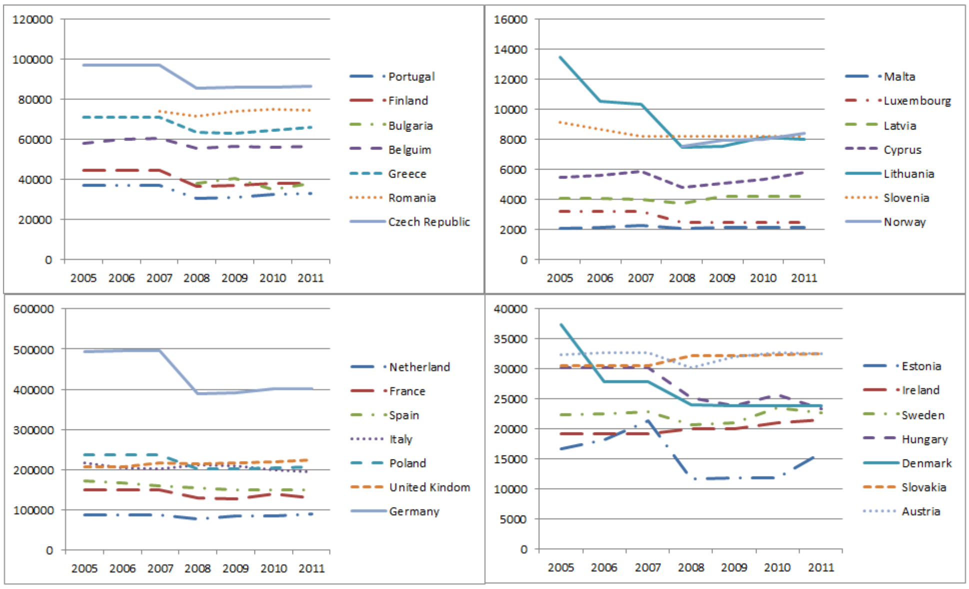
Figure 1: Allowances by year and sector



not include allowances bought. The verified emissions are emissions of the installation(s) which have been examined by a verifier. The second scope corresponds to a constant scope: it takes into account the same installations across the years (those for which verified emissions or freely allocated EUAs were reported throughout the second trading period). This "constant scope" provides time-consistent information, meaningful for a relevant trend analysis. The allowance is in the terms of tons of CO_2 equivalent. EU ETS started with the EU-25 in 2005, but the number of countries covered has since increased to 30. Bulgaria and Romania entered EU ETS in 2007, and Norway, Iceland, and Liechtenstein joined in 2008. The regulation status dummies I used in regressions are generated for each industry by country and by year.

The amount of freely allocated allowances for EU ETS members is shown in Figure 2. The starting point shows the year when the country entered EU ETS. From the graph, we notice that there is no significant cut in emission during Phase I and Phase II. The emissions cap did not decrease during those two periods. The noticeable reduction in Germany (DE) is due to those parts of allowances which are allocated by auction. Besides EU ETS regulations, other Kyoto Protocol members also started sub-national trading schemes. For example, Japan emissions trading in Tokyo started in 2010 ran by the Tokyo Metropolitan Government. Canada started emissions trading in Alberta in 2007 run by the Government of Alberta. The New Zealand Emissions Trading Scheme started in 2008. These trading schemes are smaller in scale and too new. Hence they are omitted in this chapter because EU ETS is the only international and broadly spread regulation scheme covering a longer period of time.

Figure 2: Total Allowances by Country and Year

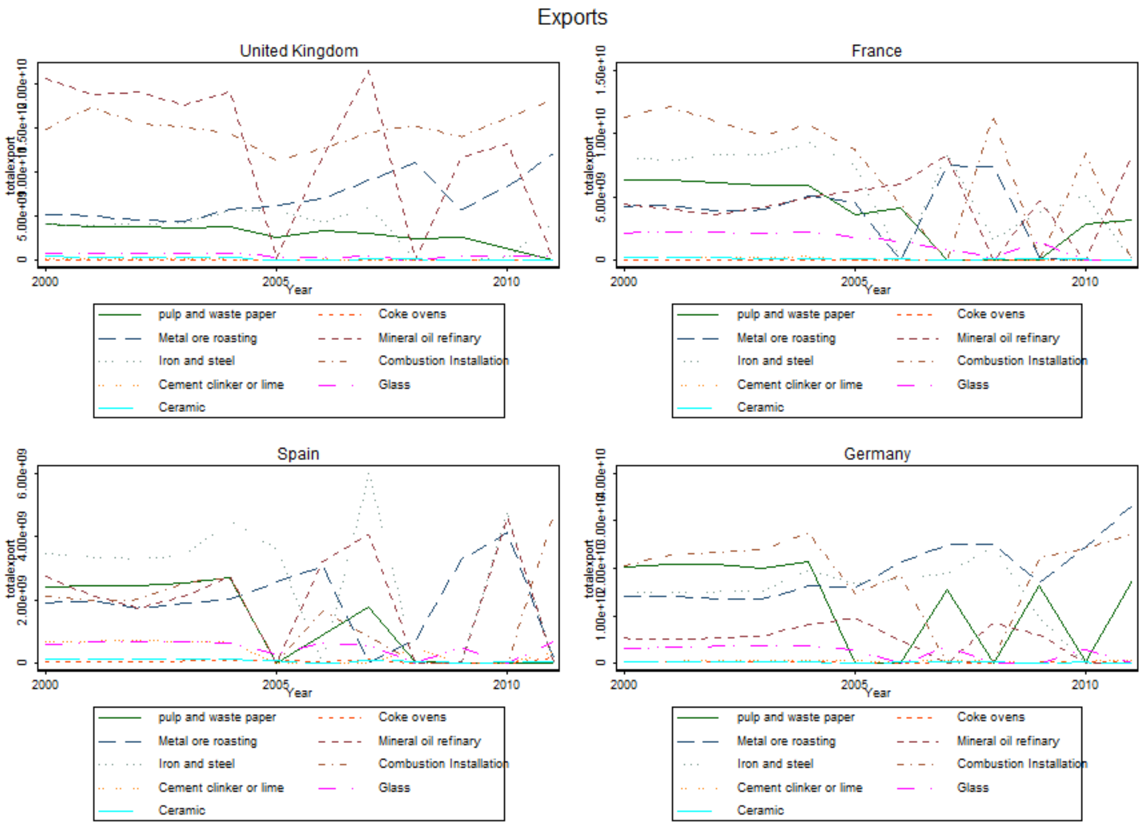


Some countries sell some proportions of allowance by auctions. Those data are not directly recorded by the CITL, but are available from other sources. Table 1 summarizes the amount EUAs auctioned or sold by countries and includes the relevant sources. In regressions I generate a dummy for each country's auction status instead of using the amount because its relatively small proportion to the total EUAs.

Table 1: Auctioned EUAs

?Auctions/Sales	2005	2006	2007	2008	2009	2010	2011	Sources
				million EUA				
Austria					0.4	0.4	0.5	www.climex.com, www.co2markt.at,www.oekv-energy.at
Germany				41	41.1	41.1	40.7	www.bmu.de, www.dehst.de
Greece								
Hungary		1.2	1.2					www.euets.com
Ireland		1.2			0.2	0.2	0.2	www.pointcarbom.com, www.ec.europa.eu
Lithuania			0.6				0.9	
Netherlands						8	4	www.dsta.nl, www.eex.de
Norway					12.7	6.4	6.4	www.regjeringen.no
United Kingdom				4	25	35.8	30.7	www.dmo.gov.uk
EU-25		2.4	1.7	45	66.7	85.5	76.9	
EU-27		2.4	1.7	45	66.7	85.5	76.9	
All countries		2.4	1.7	45	66.7	91.9	83.3	

Figure 3: Export flows in United Kingdom, France, Spain, Germany by industry



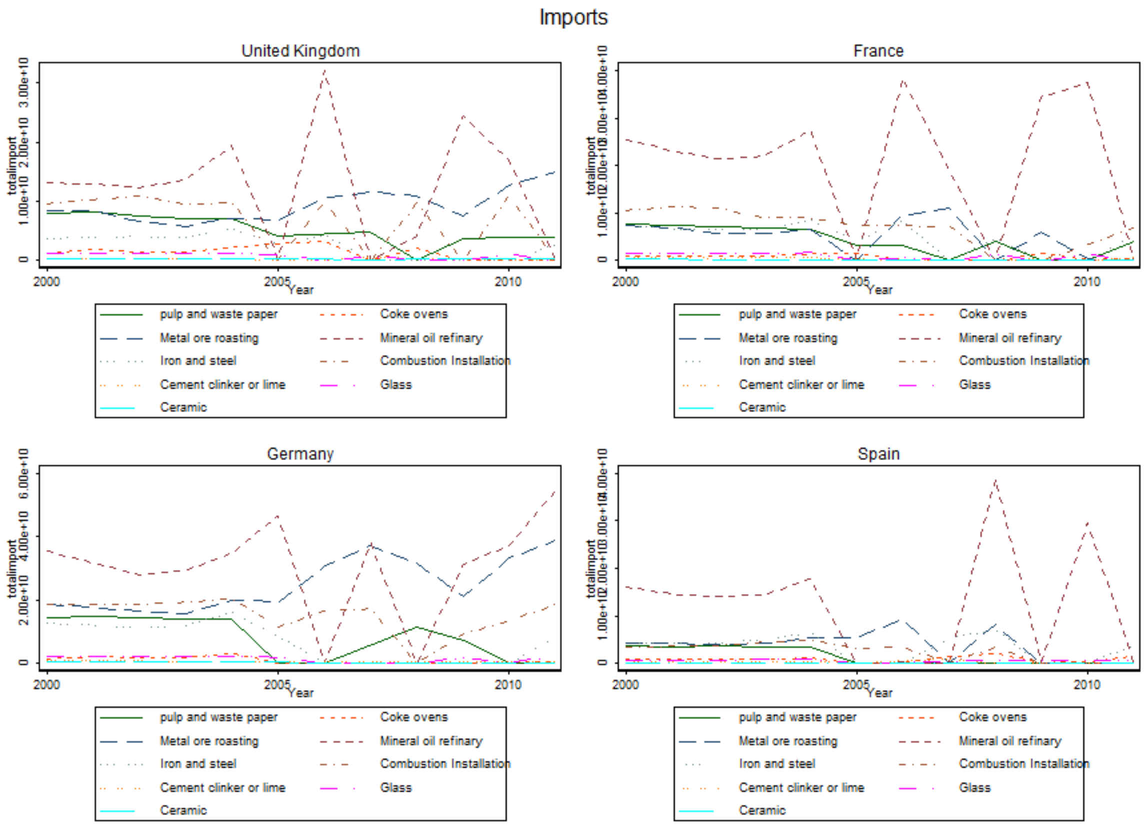
The international trade data are from EuroStat reflecting 2- or 3-digit SITC bilateral trade flows in values from 2000 to 2011. The countries participating in EU ETS are referred to as reporters. Table 2 shows how the SITC classification is matched with EU ETS industry sectors. Since the combustion installations are not defined as industrial sectors, the power generation equipment is used to approximate the demand for further expansion of combustion installations. I selected four countries: the United Kingdom and Spain, which are short in their allocated allowances, and France and Germany, which are excessive in their allowances. Their imports and exports by year and industry are shown in Figure 3 and 4. For most industries, there is no obvious trade flow change before and after EU ETS, especially for mineral oils, which shows a zigzag shape.

The necessary gravity variables are from the CEPII gravity dataset, which includes common language, GDP, population, distance, area, time difference, legal origins, GATT/WTO status and whether they have a common currency. CEPII data are only available until 2006. I expanded it to 2011 by adding GDP and population obtained from World Bank's World Development Indicators (WDI). Other gravity variables do not change over time.

Table 2: SITC matching with EU ETS industry sectors

Sectors in allowance	SIITC sectors
Combustion installations	71: power generation equipment
Pig Iron or Steel	67: Iron and steel
Metal ore roasting	28: Metalliferous ores and metal scrap
	68: Non-ferrous metals
Coke Ovens	32: Coal, coke and briquettes
Mineral oil refinery	33: Petroleum, petroleum products and related materials
Pulp, paper and Board	25: Pulp and waste paper
	64: Paper, paperboard and articles of paper pulp, of paper or of paperboard
	725: Paper mill and pulp mill machinery, paper-cutting machines and other machinery for the manufacture of paper articles
Cement clinker or Lime	661: Lime, cement, and fabricated construction materials (except glass and clay materials
Glass	664: Glass
	665: Glassware
Ceramic products by fining	666: Pottery

Figure 4: Import flows in United Kingdom, France, Spain, Germany by industry



2.6 Methodology

To estimate the effect of EU ETS on trade flows, I regress trade flows on gravity variables plus regulation status for EU ETS member countries (reporter countries above). Furthermore, the effect of auction (whether an EU ETS member country auctioned their allowances or not) on trade flows will be estimated. First a cross-sectional approach is used, and then I move to fixed effects. The difference-in-difference approach is used to control for the 'real' regulated status.[6] For all the models, regressions

[6]The real regulated status is defined if a member state in EU ETS receives less allocated allowances than it needs, either in the amount value or the finance flows. This is defined as 'short position' and 'net short position' correspondingly. Further explanations are given in the following.

Table 3: Summary Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Reporter's population	172,617	2.49E+07	2.58E+07	381,363	8.25E+07
Reporter's GPD per Capita	172,617	18112.25	10,399.7	1,579.348	56388.99
Partner's population	167,681	6.08E+07	1.90E+08	9,419	1.34E+09
Partner's population	163,865	10,280.55	12,244.89	82.67167	67,554.23
Import	172,617	2.53E+07	2.19E+08	0	1.87E+10
Export	172,617	1.81E+07	1.26E+08	0	7.00E+09
Reporter's allocation	52,356	1.55E+07	3.60E+07	0	3.85E+08
Partner's allocation	8,148	9,395,979	2.44E+07	0	1.99E+08

are on samples of imports and exports for EU ETS member countries with more than 200 partner countries, then intra-EU trade and extra-EU trade are investigated separately. The linear regression model is:

$$\log x_{ijts} = \beta_0 + \beta X_{ijt} + \gamma D + \delta R + \sigma * (sectordummies * R) + \epsilon_{ijts}$$

where X_{ijst} stands for the trade flow from country i to country j at time t in sector s. X_{ijt} includes all gravity variables such as GDP per capita and population for origins and destinations in log terms, area, distance, legal origins and common language, common boarder dummies. R stands for the regulation status for home country (origins in exports and destinations in imports). D is the full set of dummies for industries and years. For partner countries of EU ETS members, regulation policies on carbon dioxide are unclear or their emission trading policy is not comparable to EU ETS. Thus, interaction of country and year dummies are included. The interactions of regulation and industries are used to make the regulation effect more accurate because sectors are not regulated at the same time in each country.

The fixed effects model contains the same regressors in addition to the full set of dummies for importers and exporters. Dummies control for the unobserved partner characteristics, in particular, for environmental policies other than EU ETS. There are more than 20,000 groups (home country and partner country for certain industry) with 170,000 observations on imports and exports. The panel data approach deals with endogeneity, in particular for non EU ETS member countries.

In the fixed effects model, I focus on the change before and after EU ETS for its member countries. However, even all the member countries are regulated by EU ETS, they are not in the same 'position'. Thus, a method to evaluate the effect of regulation for different countries on international trade is to use the difference-in-difference approach. The data however, only include the participants and industries under EU ETS, implying that finding the appropriate control and treatment group becomes very important. According to the Climate Report for the first phase of EU ETS, most countries are actually in the long position, meaning that more allowances were allocated in the first phase than were needed by covered installations. The countries in the short positions are Ireland, Spain, Italy and the United Kingdom. Noticeably, the carbon price decreases sharply at the end of Phase I due to excessive quantity of permissions. Considering the carbon price was high at the beginning of each phase and lower in later stages of each phase, it is possible that installations in one country bought more than they sold but did not appear as net buyers because the price was high when they were selling and low when they were buying. Thus, with respect to net finance flows which are calculated for each year using the average yearly price of Phase I spot allowances weighted by yearly net flows of allowances, the United Kingdom, Spain, Italy, Austria, Ireland, Slovenia are in the net short position. France, Poland, Germany and the Czech Republic have a large proportion excessive in carbon allowances to their needed. I use these two different treatments to conduct difference-in-difference analysis.

When considering the impacts of the amount of allocated allowances on international trade flows, the situation is more complicated. Even though the regulation is forced for every EU member in larger emitting industries, the detailed allocation plans are chosen by each country. The allocated amount is endogenous because taking the emissions into account, the shortage of allowance is allocated to the industries that face less severe international competition such as combustion installations. The most common way to deal with endogeneity is to find an outside instrument, such as emission rates for each industry and each country. Unfortunately, corresponding emission rates at the 2- or 3-digit SITC levels are not available to best of my knowledge. In this chapter, heteroscedasticity is used as an instrument following Lewbels (2012). This model is listed below:

$$Y_1 = X'\beta_1 + Y_2\gamma_1 + \epsilon_1,$$

$$\epsilon_1 = \alpha_1 U + V_1$$

$$Y_2 = X'\beta_2 + Y_1\gamma_2 + \epsilon_2,$$

$$\epsilon_2 = \alpha_2 U + V_2$$

It requires that the systems in which the correlation of errors across equations are due to the presence of an unobserved common factor U. Besides all the trade related exogenous variables, emission allocation allowance is a function of trade flows. On the other hand, the trade flow is also in terms of allowances. In this model, U, V_1, and V_2 are unobserved variables that are uncorrelated with X and are conditionally uncorrelated with each other, conditioning on X. U is an omitted variable or other unobserved factor that may directly influence both Y_1 and Y_2.

Those two are correlated by an unobserved common factor U which captures the trade-off between the marginal benefit of environmental improvement and marginal cost for industries. The moments of heteroskedasticity can be shown to be correlated with the endogenous variables while uncorrelated with all the exogenous variables. When conducting the empirical analysis, I take natural log value for the allowances. For the non-regulated industries, I give them value equals to 1. The aim of this regression is to find that for regulated countries, how the change in the amount of freely allocated allowances affects international trade flows.

2.7 Results

Table 4 and 5 reports the results for the cross-sectional regressions for imports and exports of EU ETS member countries. The first column is the cross-sectional result. Column 2 and 3 include fixed effects for each country. The gravity variables provide expected results. Both the GDP for home and partner countries have positive and significant coefficients. The coefficients of distance and time difference are negative and significant at 1% level. Other variables, such as common language and colonial relationship have positive and significant coefficients.

After taking country fixed effects into account, the population effect changed relative to cross-sectional results. As expected, the regulation impact including the interaction terms have reverse signs for imports and exports. If regulation benefits manufacturers, I expect increases in exports and decreases in imports. If regulation is impeding production as a result of costs increasing, we should observe decreases in exports and increases in imports. The pooling regression shows a negative effect on exports with a coefficient -0.964 while positive effects on imports with a coefficient 0.282, hence it implies the impeding result.

In column 4, country-by-year fixed effects for home and partner countries are added to the regression. These terms also capture the effects of population and GDP changes. The interactions of fixed effects are aimed to deal with unobservable environmental or other trade policy changes that may affect trade flows. Comparing those results with column 2 and 3, there is no significant quantitative difference. The model may well capture unobservable factors by containing fixed effects.

Table 4: Pooling Regression Results

	EXPORTS				IMPORTS			
Population	1.192***	-4.729***	-4.761***		1.028***	-3.110***	-3.150***	
reporter	(0.01)	(0.43)	(0.43)		(0.01)	(0.56)	(0.57)	
GDP per capita	1.153***	0.738***	0.724***		0.711***	1.805***	1.790***	
reporter	(0.02)	(0.14)	0.14		(0.02)	(0.19)	(0.19)	
Population	0.961***	0.813***	0.814***		1.037***	0.795***	0.799***	
partner	(0.01)	(0.07)	(0.07)		(0.01)	(0.18)	(0.18)	
GPD per capita	0.719***	0.061	0.063		1.077***	0.672***	0.674***	
partner	(0.00)	(0.12)	(0.12)		(0.01)	(0.1)	(0.1)	
Interaction1	0.847***	0.791***	0.789***	0.878***	-0.722***	-0.701***	-0.699***	-0.629***
pulp paper	(0.1)	(0.1)	0.1	(0.1)	(0.16)	(0.15)	(0.15)	(0.16)
Interaction2	0.780***	1.003***	1.001***	1.024***	-0.457**	-0.382*	-0.382*	-0.351*
metal ore roasting	(0.11)	(0.11)	(0.11)	(0.11)	(0.16)	(0.15)	(0.15)	(0.16)
Interaction4	1.240***	1.346***	1.345***	1.525***	-0.284	-0.186	-0.184	-0.062
mineral oil refinary	(0.09)	(0.09)	(0.09)	(0.09)	(0.15)	(0.14)	(0.14)	(0.15)
Interaction5	1.050***	1.076***	1.074***	1.148***	-0.557***	-0.453**	-0.452**	-0.435**
pig iron or steel	(0.09)	(0.09)	(0.09)	(0.09)	(0.15)	(0.14)	(0.14)	(0.15)
Interaction6	1.120***	1.121***	1.120***	1.433***	-0.569***	-0.524***	-0.522***	-0.400**
combustion installation	(0.09)	(0.09)	(0.09)	(0.09)	(0.14)	(0.14)	(0.14)	(0.14)
Interaction7	0.774***	0.760***	0.758***	0.852***	-0.619***	-0.589***	-0.587***	-0.502***
cement and clinker or lime	(0.1)	(0.09)	(0.09)	(0.1)	(0.15)	(0.14)	(0.14)	(0.15)
Interaction8	0.587***	0.594***	0.592***	0.761***	-0.965***	-0.906***	-0.903***	-0.819***
glass	(0.09)	(0.09)	(0.09)	(0.09)	(0.15)	(0.14)	(0.14)	(0.15)
Interaction9	0.517***	0.615***	0.614***	0.764***	-1.005***	-1.006***	-1.005***	-0.904***
ceramic products by fining	(0.09)	(0.09)	(0.09)	(0.09)	(0.15)	(0.14)	(0.14)	(0.15)
Regulation	-1.110***	-0.966***	-0.964***	-0.961***	0.267	0.284*	0.282*	0.228
	(0.08)	(0.08)	(0.08)	(0.08)	(0.14)	(0.13)	(0.13)	(0.14)
Auction	-0.059		-0.026		-0.034		-0.026	
	(0.03)		(0.03)		(0.05)		(0.05)	
country fixed effect	No	Yes	Yes	No	No	Yes	Yes	No
year by country effects	No	No	No	Yes	No	No	No	Yes

Table 5: Pooling Regression Results for Gravity Variables

Gravity	IMPORTS				EXPORTS			
	Cross-sectional	Cross-sectional w/ emission	Fixed effect	Fixed effect w/ auction	Cross-sectional	Cross-sectional w/ emission	Fixed effect	Fixed effect w/ auction
Common Language	0.091	0.124	-0.035	-0.035	0.331***	0.379***	0.276***	0.276***
	0.07	0.07	0.07	0.07	0.05	0.05	0.05	0.05
Common colonizer	1.466***	1.451***	1.484***	1.484***	1.169***	1.233***	1.327***	1.327***
	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06
In Colonial Relation	0.321***	0.313***	0.364***	0.364***	0.764***	0.767***	0.818***	0.818***
	0.06	0.06	0.06	0.06	0.04	0.04	0.04	0.04
Distance	-0.000***	-0.000***	-0.001***	-0.001***	-0.000***	-0.000***	-0.001***	-0.001***
	0	0	0	0	0	0	0	0
Area	-0.000***	-0.000***	0.000***	0.000***	-0.000***	-0.000***	0.000***	0.000***
	0	0	0	0	0	0	0	0
Time Difference	-0.127***	-0.119***	0.200***	0.200***	-0.027***	-0.025***	0.278***	0.278***
	0.01	0.01	0.02	0.02	0.01	0.01	0.02	0.02
Common legal origin	0.530***	0.538***	0.585***	0.585***	0.430***	0.395***	0.408***	0.408***
	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.02
2001	-0.084*	-0.076*	-0.042	-0.042	-0.059*	-0.061*	-0.008	-0.008
	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03
2002	-0.121**	-0.114**	-0.078*	-0.077*	-0.089**	-0.092***	-0.009	-0.008
	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03
2003	-0.171***	-0.167***	-0.114**	-0.113**	-0.108***	-0.114***	0.016	0.017
	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03
2004	-0.128***	-0.120**	-0.061	-0.059	-0.148***	-0.153***	0.035	0.036
	0.04	0.04	0.05	0.05	0.03	0.03	0.03	0.03
2005	0.086	0.07	0.132*	0.134*	0.167***	0.154***	0.248***	0.251***
	0.05	0.05	0.06	0.06	0.04	0.04	0.05	0.05
2006	0.109*	0.109*	0.148*	0.152*	0.02	0.016	0.215***	0.220***
	0.05	0.05	0.07	0.07	0.04	0.04	0.05	0.05
2007	0.156**	0.141*	0.247**	0.252**	-0.025	-0.038	0.176**	0.180**
	0.05	0.05	0.08	0.08	0.04	0.04	0.06	0.06
2008	0.173***	0.167**	0.213*	0.220**	0.123**	0.130**	0.385***	0.392***
	0.05	0.05	0.08	0.08	0.04	0.04	0.06	0.06
2009	-0.102	-0.095	0.031	0.039	0.015	0.033	0.245***	0.254***
	0.05	0.06	0.08	0.08	0.04	0.04	0.06	0.06
2010	0.006		0.188*	0.197*	0.029		0.339***	0.349***
	0.05		0.08	0.08	0.04		0.06	0.06
2011	-0.076		0.124	0.135	0.175***		0.547***	0.559***
	0.05		0.08	0.09	0.04		0.06	0.07
metal and ores	-0.003	-0.099	0.105	0.105	-0.820***	-0.870***	-0.843***	-0.843***
	0.06	0.06	0.05	0.05	0.04	0.04	0.04	0.04
Coke and coal	-3.190***	-3.181***	-3.272***	-3.272***	-4.362***	-4.493***	-4.441***	-4.442***
	0.06	0.06	0.06	0.06	0.05	0.05	0.04	0.04
petroleum	-1.348***	-1.410***	-1.261***	-1.260***	-2.391***	-2.412***	-2.361***	-2.361***
	0.06	0.06	0.06	0.06	0.04	0.04	0.04	0.04
iron and steel	-1.216***	-1.246***	-1.046***	-1.046***	-1.207***	-1.212***	-1.100***	-1.100***
	0.06	0.06	0.05	0.05	0.04	0.04	0.04	0.04
combustion installation	-2.061***	-2.100***	-1.820***	-1.820***	-1.462***	-1.489***	-1.320***	-1.320***
	0.06	0.06	0.05	0.05	0.04	0.04	0.04	0.04
cement and lime	-3.795***	-3.834***	-3.640***	-3.640***	-3.843***	-3.858***	-3.824***	-3.824***
	0.06	0.06	0.06	0.06	0.04	0.04	0.04	0.04
glass	-2.546***	-2.582***	-2.379***	-2.379***	-2.493***	-2.513***	-2.414***	-2.413***
	0.06	0.06	0.06	0.06	0.04	0.04	0.04	0.04
pottery	-4.381***	-4.464***	-4.157***	-4.156***	-4.875***	-4.871***	-4.817***	-4.817***
	0.06	0.06	0.06	0.06	0.04	0.04	0.04	0.04
R-sqr	0.495	0.499	0.544	0.544	0.542	0.548	0.579	0.579

* $p < 0.05$, ** $p < 0.01$, ***$p < 0.001$

From table 4, imports increase by 0.28 log-point as a result of the regulation, while exports decrease by 0.96. The differences in magnitudes between imports and exports could be explained as the regulation having greatly changed the behavior of manufacturers. The pollution haven hypothesis implies that as those manufacturers have less comparative advantage than before, their exports to other countries decrease. However, for imports, the case is more complicated.

If manufacturers cut their production in the short run, the total domestic production will decrease as imports increase. In the long run, they may adjust their investment or move to a lower emission technology. Therefore, I expect a smaller impact on the value of imports than exports. The coefficient for auctions is not significant, which may due to a relatively small amount being auctioned compared to grandfathered allowances.

The interactions of industries and regulation status all have significant coefficients except for the mineral oil refinery in imports. The exports for mineral oil refinery increase significantly, while imports decrease. One explanation for this deviation is that the factors that could affect mineral oil trade are more complicated even after controlling for trade and environmental policies. The corresponding SITC is Petroleum, petroleum products and related materials. Especially for petroleum, imports are quite stable. Hence, its result is less obvious when compared to other sectors.

The interaction terms coefficients of all industries show significant decreases in imports and increases in exports, although the pure effect of regulation raises imports and reduces exports. If we combine the pure effect of regulation and the interaction terms, for cements, glass, ceramics and pulp papers, EU ETS decreases exports and also increases imports. While for iron steel industry which has excessive allowances, EU ETS actually increases its exports, decreases imports.

Next I use the same model as in columns 2 and 3, but separate the sample into the intra-EU and extra-EU trade since within-EU trade accounts for a large portion of total trade flows in EU ETS member countries. These results are presented in Table 6 for exports and Table 7 for imports. The coefficients of the regulation dummies imply that the overall dimension of trade shifts depends on intra-EU trade. The results suggest that EU ETS changed the trade pattern within EU because of the unbalanced freely allocated allowances among countries and industries. On the extra EU trade side, the direction of regulations effects varies across industries.

Table 6: Separating Intra EU and Extra EU results: Exports

	EXPORTS					
	Intra EU	Extra EU	Intr EU	Extra EU	Intra EU	Extra EU
Regulation	-0.536***	0.056	-0.434**	-1.337***	-0.541***	0.054
	(0.12)	(0.09)	(0.13)	(0.11)	(0.12)	(0.09)
Interaction1	0.326*	-0.250*	0.468**	1.145***	0.330*	-0.248*
pulp paper	(0.15)	(0.11)	(0.16)	(0.12)	(0.15)	(0.11)
Interaction2	0.486**		0.604***	1.326***	0.495**	
metal ore roasting	(0.16)		(0.17)	(0.14)	(0.16)	
Interaction3						
Coke ovens						
Interaction4(mineral oil refinary)	1.405***	0.239*	1.641***	1.712***	1.409***	0.241*
	(0.14)	(0.1)	(0.15)	(0.11)	(0.14)	(0.1)
Interaction4	1.109***	0.011	1.178***	1.398***	1.115***	0.012
mineral oil refinary	(0.14)	(0.1)	(0.15)	(0.11)	(0.14)	(0.1)
Interaction5	0.542***	0.077	0.545***	1.750***	0.545***	0.079
pig iron or steel	(0.14)	(0.1)	(0.15)	(0.11)	(0.14)	(0.1)
Interaction6	0.373*	-0.340**	0.493**	1.055***	0.380**	-0.339**
combustion installation	(0.15)	(0.1)	(0.16)	(0.12)	(0.15)	(0.1)
Interaction7	0.431**	-0.432***	0.548***	1.052***	0.439**	-0.432***
cement and clinker or lime	(0.14)	(0.1)	(0.15)	(0.11)	(0.14)	(0.1)
Interaction8	0.176	-0.401***	0.235	1.068***	0.18	-0.399***
glass	(0.14)	(0.1)	(0.15)	(0.12)	(0.14)	(0.1)
Interaction9					0.081	-0.036
ceramic products by fining					(0.07)	(0.04)
country FE	Yes	Yes	No	No	Yes	Yes
country by year FE	No	No	Yes	Yes	No	No
R-sqr	0.649	0.533	0.658	0.547	0.649	0.533

* $p < 0.05$, ** $p < 0.01$,*** $p < 0.001$

Table 7: Separating Intra EU and Extra EU results: Imports

	IMPORTS					
	Intra EU	Extra EU	Intr EU	Extra EU	Intra EU	Extra EU
Regulation	0.122	-0.266*	-0.048	-0.274*	0.116	-0.266*
	(0.13)	(0.13)	(0.15)	(0.13)	(0.13)	(0.13)
Interaction1	-0.549***		-0.350*		-0.540***	
pulp paper	(0.16)		(0.18)		(0.16)	
Interaction2	0.125	0.379		0.118	0.126	0.382
metal ore roasting	(0.19)	(0.23)		(0.17)	(0.19)	(0.23)
Interaction3			0.237	0.282		
Coke ovens			(0.21)	(0.24)		
Interaction4(mineral oil refinary)	-0.325*	0.358*	-0.24	0.519***	-0.315*	0.359*
	(0.15)	(0.14)	(0.17)	(0.14)	(0.15)	(0.14)
Interaction4	-0.13	0.212	-0.028	0.193	-0.126	0.214
mineral oil refinary	(0.15)	(0.14)	(0.17)	(0.14)	(0.15)	(0.14)
Interaction5	-0.234	0.133	-0.106	0.255	-0.226	0.133
pig iron or steel	(0.15)	(0.13)	(0.17)	(0.13)	(0.15)	(0.13)
Interaction6	-0.584***	0.1	-0.437*	0.169	-0.573***	0.1
combustion installation	(0.15)	(0.14)	(0.17)	(0.14)	(0.15)	(0.14)
Interaction7	-0.575***	-0.257	-0.435**	-0.191	-0.566***	-0.256
cement and clinker or lime	(0.15)	(0.14)	(0.17)	(0.14)	(0.15)	(0.14)
Interaction8	-0.685***	-0.532***	-0.518**	-0.443**	-0.678***	-0.531***
glass	(0.15)	(0.14)	(0.17)	(0.14)	(0.15)	(0.14)
Interaction9					-0.113	0.03
ceramic products by fining					(0.07)	(0.06)
country FE	Yes	Yes	No	No	Yes	Yes
country by year FE	No	No	Yes	Yes	No	No
R-sqr	0.631	0.495	0.639	0.51	0.631	0.495

$*p < 0.05$, $**p < 0.01$, $*** p < 0.001$

For example, exports from EU countries of iron steel are actually increasing after EU ETS as a result of excessive freely allocated allowances to those industries. On the other side for iron steel, regulations decrease imports. Similarly, the results are more significant on exports than imports.

The auction status is still insignificant. It suggests that countries that tried auction rather than giving allowances away export more to other EU countries and import more from non-EU countries. Notably, intra EU exports of combustion installations related equipment increases significantly. A reason for this increase is that if the national allocation plan allocates the shortage mostly on the combustion installation sectors, it may increase the demand for fewer emissions and more efficient equipment. Similarly, the increase in exports to EU countries in combustion installation sectors could be explained by the same reason.

In order to further test the pollution haven effect, I separate extra EU trade partners into five groups according to their income level. The country class level is obtained from World Bank. The results are shown in Table 8. The detailed results also vary across industries; however, the trend implies that after EU ETS, exports to relatively poor countries decrease, while they increase to the rich countries. This result is consistent with the right side of the U-shape environmental Kuznets curve. On the imports side, after EU ETS, EU countries are importing more from lower middle income and upper middle income countries but not from lower income countries. This result is consistent with the left side of the U-shaped Kuznets curve. The pollution haven may gravitate to middle income and upper middle income countries.

Table 8: Regression Results by Countries' Income Level

	Export by Income level					Import by income level				
	High Non-OECD	High OECD	Low	Lower Middle	Upper Middle	High Non-OECD	High OECD	Low	Lower Middle	Upper Middle
Regulation	-1.710***	0.481*	-0.479	-0.947***	-1.434***	-0.85	-0.535*	-0.23	-0.455	0.282
	(0.27)	(0.23)	(0.39)	(0.23)	(0.17)	(1.2)	(0.25)	(2.26)	(0.39)	(0.31)
Interaction1	1.468***	-0.176	-0.239	0.517*	1.194***	0.87	-0.405	-0.704	0.394	-0.210
pulp paper	(0.31)	(0.28)	(0.37)	(0.25)	(0.2)	(1.28)	(0.31)	(2.48)	(0.48)	(0.36)
Interaction2	1.672***	-1.910***	-0.06	0.688*	1.369***	0.816	0.860*	-0.411	0.072	-0.138
metal ore roasting	(0.35)	(0.35)	(0.42)	(0.28)	(0.22)	(1.25)	(0.4)	(2.28)	(0.45)	(0.35)
Interaction4	2.321***	0.339	-1.738**	1.050***	1.741***	1.16	0.612*	-2.206	-0.248	0.085
mineral oil refinary	(0.29)	(0.26)	(0.55)	(0.24)	(0.18)	(1.21)	(0.28)	(2.3)	(0.42)	(0.33)
Interaction5	1.884***	0.533*	0.357	0.790***	1.494***	0.848	0.291	-0.403	0.259	-0.198
pig iron or steel	(0.28)	(0.25)	(0.38)	(0.23)	(0.18)	(1.21)	(0.28)	(2.29)	(0.41)	(0.32)
Interaction6	2.158***	0.299	-0.223	1.200***	1.749***	0.598	0.211	-0.327	0.652	-0.253
combustion installation	(0.28)	(0.25)	(0.37)	(0.23)	(0.18)	(1.21)	(0.27)	(2.26)	(0.41)	(0.32)
Interaction7	1.362***	-0.623*	0.472	0.594*	1.126***	0.324	0.066	-0.599	0.59	-0.211
cement and clinker or lime	(0.3)	(0.26)	(0.37)	(0.25)	(0.19)	(1.22)	(0.28)	(2.27)	(0.41)	(0.33)
Interaction8	1.472***	-0.274	0.018	0.424	1.171***	0.161	-0.213	-0.875	0.08	-0.537
glass	(0.28)	(0.25)	(0.4)	(0.24)	(0.18)	(1.22)	(0.27)	(2.29)	(0.42)	(0.33)
Interaction9	1.709***	-0.177	-0.381	0.394	1.086***	-0.44	-0.268	-0.208	-0.088	-1.094***
ceramic products by fining	(0.29)	(0.25)	(0.38)	(0.24)	(0.18)	(1.21)	(0.27)	(2.27)	(0.41)	(0.33)
R-sqr	0.537	0.623	0.431	0.526	0.56	0.432	0.665	0.564	0.484	0.497

* $p < 0.05$, ** $p < 0.01$,*** $p < 0.001$

The two difference-in-difference regressions give similar results as the fixed effects model in Table 9. The magnitude of the effect of regulation on exports and imports are -0.9 and 0.26 correspondingly. The total effects of regulations on member countries that are in short position show a decrease in exports and an increase in imports. The interaction term of net short positions and treatment (regulation) suggests that those countries face both as increase in imports and exports (0.189 comparing to 15.139) after the regulation. This result implies that the current EU ETS policies push countries with more demand in carbon emissions into a disadvantage vis-á-vis international competition. Table 10 shows how the quantity of allocated allowances affects international trade flows. The two panels of this table stand for imports and exports respectively. All columns control for country $\times$ year fixed effects. Columns (1) does not control for the possible endogeneity of allowances. On exports side, one percent change in freely allocated allowances will bring up exports by 2.7% and this result is significant at 1% level. Auction status is significant and negative in this analysis. Imports side has all opposite results to exports, allowances has negative impact on imports and auction has positive impacts on the value of imports, though these results are not significant. These results convinced the hypothesis that more freely allocated allowances give more advantages to the producers, which means more exports, but less imports. After controlling for the endogeneity, there is not change for the sign, but the coefficient are larger. Also, I separate the samples into intra EU and extra EU trade as before, it yields constant results, and only on exports coefficients are significant. The effect of the amount of freely allocated allowances is larger within EU than extra-EU. The IV parts are plausible taking the excessive allowances into account. Moreover, as discussed above, the regulations change the manufacturers' behavior rather than the demand in the market. Hence, for exports the results are significant.

Table 9: Diff-in-Diff Results

	EXPORTS		IMPORTS	
	Short Position	Net-short position	Short Position	Net-short position
Regulation	-1.006***	-0.970***	0.257	0.280*
	(0.08)	(0.08)	(0.13)	(0.13)
Interaction1	0.820***	0.793***	-0.685***	-0.698***
pulp paper	(0.1)	(0.1)	(0.15)	(0.15)
Interaction2	1.030***	1.006***	-0.369*	-0.381*
metal ore roasting	(0.11)	(0.11)	(0.15)	(0.15)
Interaction4	1.378***	1.347***	-0.16	-0.182
mineral oil refinary	(0.09)	(0.09)	(0.14)	(0.14)
Interaction5	1.108***	1.090***	-0.438**	-0.450**
pig iron or steel	(0.09)	(0.09)	(0.14)	(0.14)
Interaction6	1.150***	1.127***	-0.503***	-0.521***
combustion installation	(0.09)	(0.09)	(0.14)	(0.14)
Interaction7	0.781***	0.754***	-0.572***	-0.585***
cement and clinker or lime	(0.09)	(0.09)	(0.14)	(0.14)
Interaction8	0.618***	0.594***	-0.883***	-0.902***
glass	(0.09)	(0.09)	(0.14)	(0.14)
Interaction9	0.644***	0.619***	-0.982***	-1.004***
ceramic products by fining	(0.09)	(0.09)	(0.14)	(0.14)
Auction	-0.069*	-0.053	-0.064	-0.028
	(0.03)	(0.03)	(0.05)	(0.05)
Short position	-2.930***		-7.042***	
	(0.2)		(0.57)	
Short*	0.161***		0.127**	
time control	(0.03)		(0.04)	
timecontrol	0.490***	0.553***	0.147	0.197*
	(0.07)	(0.07)	(0.09)	(0.08)
Net-short position		0.063		0.01
		(0.06)		(0.05)
Net-short*		0.189***		15.139***
time control		(0.04)		(2.32)
R-sqr	0.579	0.579	0.544	0.544

* $p < 0.05$, ** $p < 0.01$,*** $p < 0.001$

Table 10: Allowances and Auction Effects on Bilateral Trade Flows

		Fixed effects			
		No control	IV	IV Intra	IV Extra
	Exports				
Allocation		0.027***	0.159***	0.329***	0.127***
		(0.01)	(0.01)	(0.02)	(0.01)
Auction		-0.604***	-0.053	0.132	-0.087
		(0.23)			
	R-sqr	0.59	0.58	0.59	0.54
	Imports				
Allocation		-0.02	-0.002	1.46	0.00
		(0.01)	(0.020)	(5.02)	(0.06)
Auction		0.82			
		(3.98)			
	R-sqr	0.540	0.556	0.59	0.51

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

2.8 Robustness

I conduct several robustness checks. Results are reported in Table 11. The first robustness check is to use three-year windows for the dataset since the industries could make adjustment according to the regulations, and those adjustments will not manifest themselves in trade flows until several years later. The second one is to limit the sample to EU-15 countries only because EU-15 countries are forced into EU ETS rather than opted in. The third robustness check is changing the contained industrial sectors in the sample, such as excluding iron and steel sectors or combustion installations.

The three-year window gives the same results as before. EU-15 countries which face the emission cut have a significant increase in exports, while the change in exports is not significant. After excluding the combustion sector (SITC 71), the results are still robust. Also, according to the *Climate Report*, the sector with the largest excessive allocated allowance is iron and steel. Excluding iron and steel sectors, the regulation effect is still negative, but insignificant. When excluding both combustion installation and iron and steel sectors, all results are unchanged.

Table 11: Robustness Check

	EXPORTS					IMPORTS				
	Three-year window	Exempt non-industrial sector	Exempt Iron and steel sector	Exempt Both two	EU15	Three-year window	Exempt non-industrial sector	Exempt Iron and steel sector	Exempt Both two	EU15
Regulation	-0.923***	-0.782***	-0.041	-0.803***	0.292***	0.271	-0.104	-0.111	0.347**	-0.14
	(0.1)	(0.08)	(0.07)	(0.08)	(0.08)	(0.17)	(0.09)	(0.09)	(0.13)	(0.17)
Interaction1	0.733***	0.703***	-0.335***	0.507***	-0.232*	-0.733***	-0.299*	-0.331**	-0.776***	-0.267
pulp paper	(0.13)	(0.1)	(0.09)	(0.1)	(0.09)	(0.21)	(0.12)	(0.12)	(0.16)	(0.19)
Interaction2	1.026***	0.865***		0.821***		-0.417*			-0.458**	0.007
metal ore roasting	(0.14)	(0.11)		(0.11)		(0.21)			(0.16)	(0.19)
Interaction4	1.416***	1.295***	0.181*	1.054***	0.534***	-0.074	0.204	0.181	-0.282*	0.171
mineral oil refinary	(0.11)	(0.09)	(0.08)	(0.09)	(0.08)	(0.19)	(0.1)	(0.1)	(0.14)	(0.18)
Interaction5	1.139***	1.027***			0.142	-0.460*	-0.046			-0.189
pig iron or steel	(0.11)	(0.09)			(0.08)	(0.19)	(0.1)			(0.18)
Interaction6	1.194***		-0.025		0.201*	-0.460*		-0.161		-0.169
combustion installation	(0.11)		(0.08)		(0.08)	(0.18)		(0.1)		(0.17)
Interaction7	0.561***	0.689***	-0.405***	0.452***	-0.190*	-0.543**	-0.177	-0.234*	-0.670***	-0.371*
cement and clinker or lime	(0.12)	(0.09)	(0.08)	(0.09)	(0.09)	(0.19)	(0.1)	(0.1)	(0.14)	(0.18)
Interaction8	0.561***	0.530***	-0.552***	0.323***	-0.382***	-0.904***	-0.470***	-0.533***	-0.937***	-0.471**
glass	(0.11)	(0.09)	(0.08)	(0.09)	(0.08)	(0.19)	(0.1)	(0.1)	(0.14)	(0.18)
Interaction9	0.527***	0.550***	-0.574***	0.282**	-0.283***	-0.951***	-0.589***	-0.624***	-1.046***	-0.662***
ceramic products by fining	(0.12)	(0.09)	(0.08)	(0.09)	(0.09)	(0.19)	(0.1)	(0.1)	(0.14)	(0.18)
Auction	0.038	0.002	-0.04	0.017	0.093**	-0.041	-0.047	-0.016	-0.032	0.02
	(0.05)	(0.04)	(0.03)	(0.04)	(0.03)	(0.06)	(0.05)	(0.05)	(0.05)	(0.05)
R-sqr	0.583	0.584	0.586	0.595	0.643	0.538	0.542	0.545	0.545	0.544

* $p < 0.05$, ** $p < 0.01$,*** $p < 0.001$

2.9 Conclusion and Further study

In this chapter, I use the cross-section, cross-time bilateral trade flow data to evaluate the EU Emission Trading Scheme effect on international trade with a gravity model based on the pollution haven hypothesis. The impact of auctions is also examined. The difference-in-difference approach is used to study the regulation effect on countries which are in shortage of allowances. To examine the effects more precisely, the samples are separated into intra EU trade and extra EU trade. Moreover, trade flows changes are also examined for different country income level. The effects of the amount of freely allocated allowances on trade flows are also investigated through an IV model.

EU ETS increases imports and decreases exports. The separate regression implies that the pollution haven is generated with respect to the middle income and upper middle income countries. The member countries which are in the (net) short position do face reductions in comparative advantage. The effect of auctions is not significant due to the small portion of the total allowances. Those results suggest that there is a pollution haven effect caused by EU ETS among EU countries.

The empirical results in this chapter suggest several importation policy implications. EU ETS increases imports into its member countries and decrease exports by a larger amount. Especially for countries in the short or net-short position in emission trading, their comparative advantage in international trade is weakened by EU ETS. The further tightening of the emission cap or increases in the compliance cost for producers (auctioned) could disadvantage regulated countries in the international competition. Pollution haven was generated by EU ETS, particularly for industries short in allowances. Considering that greenhouse gas is a global pollutant, further sacrificing EU economic benefits may not be an optimal choice.

Even though, there are still excessive allowances for current EU ETS policies. For some industries, such as iron and steel, the total effect of EU ETS is to increase their comparative advantages. Thus, in order to achieve the emission goals in the third phase, their allocated allowances could be cut, or auctioned. Also, according to my results, the trade pattern is controllable by varying the freely allocated allowances. But, the effect of auction on international trade is still unclear.

The trade shifts within EU away from the countries with abundant permissions to others. The domestic production and foreign direct investment should also be investigated since the pollution haven hypothesis also suggests that polluted industries relocated from countries with stringent regulations to the countries with less stringent regulations. Controls for the partners corresponding regulations would be beneficial. Also, how to measure those different regulations and compare them with EU ETS merits further study.

CHAPTER III

TESTING THE POLLUTION HAVEN HYPOTHESIS OF EUROPEAN UNION EMISSIONS TRADING SCHEME, INTERNATIONAL TRADE VERSUS FOREIGN DIRECT INVESTMENT

3.1 Introduction

As the largest international cap-and-trade environmental regulation, EU ETS is trying to limit the total emissions of green house gas. Based on pollution haven hypothesis, running cap-and-trade scheme may increase the cost of abatement, thus harm the production in regulated industries. There is no clear answer whether EU ETS affect firms' behavior and comparative advantages on international competitions. Till today, EU ETS has completed two phases. The 'cap' for all countries are cut dramatically from phase I to phase II. There is also adjustments among industries. Phase I ran from January, 1, 2005 to 31st December, 2007 and covered only carbon dioxide emissions from energy activities (combustion installations with a rated thermal input exceeding 20MW, mineral oil refineries, coke ovens), production and processing of ferrous metals, mineral industry (cement clinker, glass and ceramic bricks) and pulp, paper and board activities. Phase II ran from January, 1, 2008 to December, 31, 2012. EU ETS, like other environmental regulations, generates both benefits of emissions also costs for conducting them. Those effects could be reflected in both international trade and FDI.

In the first chapter, I show that EU ETS impedes regulated industries in international competition by decreasing exports and increasing imports. This result confirmed pollution haven hypothesis (PHH) of EU ETS. FDI, which has been shown as a substitution of bilateral trade (Markusen 2002) also acts as an important role in international competitions. Given the intra-industry trade flows change, how firms' FDI decisions change after EU ETS is an important issue to further verify PHH. Based on Xing and Kolstad (2000), if environmental regulations generate distortions in the operation of polluting industries, the multinational enterprise may initially respond with the intra-firm transfer of its production facility, or increase the investment in its subsidiaries located in the country with lenient regulation. These adjustments plus relocation of the entire plants will change FDI flows. Moreover, EU ETS, as a relatively new launched regulation scheme, firms may not be able to make relocation decisions in short run. Thus, FDI is a great indicator of testing PHH.

In my model I introduce a third factor, emission of carbon dioxide into Markusen (2002)'s model, combined both national exporting enterprises and horizontal multinational enterprises (HMNEs). National exporting enterprises have exports but no FDI while HMNEs do foreign direct investment but no exports. Assuming free entry and exit, the numbers of exporting enterprises and HMNEs are endogenous. A general equilibrium model shows that the numbers of exporting enterprises and HMNEs depend on a complex nonlinear relationships between trade, FDI, trade costs and investment costs. It provides us with some clues as a guide for empirical study of FDI and international trade flows.

Markusen (2000)'s model assumes that all the firms face the same efficient factor. However, when firms are heterogeneous, cap-and-trade environmental policy with freely allocated allowances may affect firms differently since some firms receive subsidies while other have to pay taxes. To further study entry and exit of national exporting enterprises and horizontal multinational enterprises, I add a heterogeneous productivity shocks upon entry. To simplify the model, I keep only two production factors, labor and emissions of carbon dioxide. The model suggests a new aspect for the theory of environmental regulations with substitutions of FDI and international trade flows. My model suggests that there will be a reduction for both inward FDI as well as outward FDI.

Moreover, I conduct an empirical study of the effects on FDI after controlling international trade flows and other related factors. The data merges FDI flows with 3-digit SITC classification trade flows for EU ETS member countries. Based on the theoretical model derived in section III, domestic price index, import price index, wage index and production index in NACE Revise 2 are also contained into regression. Since the correspondence of NACE Revision 2 and SITC are far from good in current research, I build my own correspondences between NACE Revision 2 and SITC to help merge the data. The coefficient of regulation dummy verified PHH that environmental regulation decrease inward FDI to regulated countries, while there is no increase for outward FDI to unregulated countries.

Many studies examine the empirical evidences on PHH as it pertains to FDI or relocation of firms. A large number of them fails to find significant evidences. They apply different ways to define the stringency of environmental regulation and pollution density of industries. Earlier work, such as Lucas, Wheeler and Hettige (1992) and Leonard and Duerksen (1980) examines the foreign investment in polluting industries and the growth rate of polluting factories. However, none of these measurements suggest a significant causal relationship between the location of pollution-intensive industries and environmental regulation. Leonard and Duerksen (1980) examines whether the growth of U.S. investment in developing countries exceed other investment growth rate. However, they do not find evidence to prove this hypothesis. In fact, the gap between U.S. investment in developing countries versus developed countries widened for some polluting industries. Lucas, Wheeler and Hettige (1992) tests whether the OECDs environmental policies drive dirty industries to developing countries. They also use the toxin emission density to measure the polluting industries and regress it on GDP and the growth rate of GDP per capital. Even though they do find poorest countries have highest growth rate of polluting industries, but insufficient to show that the environmental regulation contribute to this growth.

Similarly, some earlier research restricted within U.S. domestic environmental regulation did not reach significant results either. McConnell and Schwab (1990) use a location model to test the relationship between the location of the automobile industry and state-level environmental regulations. Batrtik (1988) also applies a location decision model to examine new factories opening by the Fortune 500 firms from 1972 to 1978 with state spending on pollution control and compliance costs of regulated industries in state-level. His result also shows that none of the environmental regulations significantly affect location decisions. However, after controlling for the endogeneity and unobserved heterogeneity across locations by using panel data in period from 1963 to 1992, Becker and Henderson (2000) find striking result that plant births for polluting industries in non-attainment counties which are subjected to more stringent environmental policy comparing to attainment counties were $26-45\%$ lower. Comparing to previous literature, panel data allow them to control for unobserved heterogeneity across locations and they use country-level data instead of state-level data. But there is still no significant results found. Keller and Levinson (2002) claim that the endogeneity problems are partly responsible for the failure of the earlier literature to find significant effects. In their paper they also use U.S. state-level FDI inflows data from 1977 to 1994 and pollution abatement costs per unit of output. The replication of earlier OLS regression does provide insignificant results, while after adjusting state effects, they find the coefficient on abatement costs is negative and significant.

Others have examined data for different countries. Wagner and Timmins (2009) study this issue by analyzing the impact of environmental regulations on the outward FDI of German manufacturing industries over 1996 and 2003. They emphasize the need to control for externalities resulting from FDI agglomeration, proxied by the total stock of inward FDI in the destination country. Their two-step estimator controls for endogenous time-varying determinants of FDI flows and unobserved heterogeneity at the country level. Their results show that the total stock of FDI is statistically significant for all six industries. Edward Anderson and Richard Kneller (2012) examine the environmental regulation impact on UKs FDI outflows. They apply heterogeneous firm models of international trade. Their result suggests that the environmental regulations are not a robustly significant determinant of the internationalization decision. Furthermore, they do not find robust evident that dirty multinational enterprises are more likely to locate in countries with lax environmental policy than cleaner ones. Cole and Elliott (2005) investigate the relationship between US outward FDI and factor endowments across sectors to Mexico and Brazil. Although imports from Mexico have grown more rapidly than exports to Mexico, no evidence is found to suggest that North American Free Trade Agreements is increasing displacement to Mexico. The capital constraints explain why the pollution haven does not have a wide spread.

There are several differences between this chapter and the current literature. First, unlike most of the early research which focuses on local pollutants and overall environmental regulations by generating abatement cost for the firms, I study the pollution haven effect caused by a single important environmental regulation scheme, EU ETS, a cross-country regulation focusing on a global pollutant, carbon dioxide. Besides the issues mentioned in chapter 1 about free riders, possible carbon leakage that are quite different from local pollutants, my study isolates the effect of EU ETS to provide more implication for further improvement and expansion of green-house-gas cap-and-trade schemes not only within EU, but also the rest of the world.

Also, rather than focusing only on FDI, in this chapter, I build a model that consists of both FDI and international trade flows which are taken as substitutes.

The inclusion of both could give a clearer understanding of the effect of EU ETS and whether it generates a pollution haven effect or not. In order to explain how the flows change and substitute for each other, the endogenous determination of the number of firms, firms' efficiency, and entry and exit are introduced into the model as well.

The model suggests that the output of regulated firms is lower than that of unregulated firm given the same productivity. If two different regulated firms are under a uniform freely allocated allowances scheme, the more efficient one is more likely to exit the market. It is plausible that EU ETS will not only decrease FDI inward flows because of higher cost of regulation, but it will also decrease FDI outward flows because efficient firms are driven out of the market. Empirical evidence verifies the model's results. FDI inward flows greatly reduced because of EU ETS, while outward flows also decrease slightly. However, none of those results are statistically significant.

This chapter is outlined as following. In section II, I describe EU ETS and its possible outcomes in detail. In section III, a 2×2 model with labor, capital and emission as production factors is introduced. Section IV simplifies the model with only labor and emissions but heterogeneity of firms is added. Section V describes the empirical study of EU ETS impacts on FDI. I also discuss the results in this section. The chapter's conclusion follows in section VI.

3.2 European Union Emission Trading System

As noted above in the previous chapter, EU ETS is the first large emission trading scheme in the world encompassing 27 EU countries plus Iceland, Norway, and Liechtenstein, covering more than 10,000 installations with a net heat excess of 20 MW in energy and industrial sectors which are collectively responsible for half of EU's emissions of carbon dioxide. It was launched on January, 1, 2005 as an outcome of the Kyoto Protocol. There are three phases of EU ETS. Phase I ran from January, 1, 2005 to 31st December, 2007 and covered only carbon dioxide emissions from energy activities (combustion installations with a rated thermal input exceeding 20MW, mineral oil refineries, coke ovens), production and processing of ferrous metals, mineral industry (cement clinker, glass and ceramic bricks) and pulp, paper and board activities. Phase II ran from January, 1, 2008 to December, 31, 2012. During this period, EU ETS includes revised monitoring and reporting rules, more stringent emissions caps and additional combustion sources. New industries were included, such as airlines being added at the beginning of 2012. Phase III started on 1st January 2013 and will go until December, 31, 2020. This period will bring major changes, such as harmonized allocation methodologies and inclusion of additional greenhouse gases and emission sources. EU ETS will be expanded to include petrochemicals, ammonia and aluminum industries and additional gases in 2013. The cap will be cut by as much as 20% compared to Phase II. This chapter covers the first two phases of EU ETS and studies how the current policies affect firms' performances.

In the first two phases, the scheme initially distributed most of the quotas through grandfathering– freely allocated allowances according to each member countries' Kyoto Protocol emission target. For each EU ETS phase, the total quantity of allowance to be allocated by each Member State is defined in the Member State National Allocation Plan (NAP) (equivalent to its UNFCCC-defined carbon account.) The European Commission has oversight of the NAP process and decides if the NAP fulfills the 12 criteria set out in Annex III of the Emission Trading Directive (EU 2003/87/EC). The first and foremost criterion is that the proposed total quantity is in line with a Member States Kyoto target. The distribution of emission allowances also differs across phases. Phase I is based on historical emissions and installation levels.[1] In

[1]The detailed methods for different sectors are varied. For example, the combustion installations are equal their 2002 direct emissions multiply projected output growth rate between 2002 and the first phase then multiply by change in energy per unit output required target between 2002 and the first phase. Also, those values are also adjusted by the possible growth rate.

Phase II, besides historical emissions and installation levels, several other options are added for chosen, such as option 2 based on historic output/capacity ratio; option 3 based on benchmarking; option 4 based on installation-level projections using any metric (emissions, input, output); and option 5 based on the marginal abatement cost. The choice of which option to apply rests with each member state. But in Phase III, rather than freely distributed, as much as 50% of allowances will be auctioned. In the previous two phases only a small amount of allowances were distributed via auction, 5% and 10% in Phase I and Phase II respectively.

The main participants in the allocation process are the European Commission, the member state governments, and firms would be the main recipients of allowances. The role of these participants varies according to the two main issues to be decided: the "macro" decision concerning the total number of allowances to be created by each member state, and the "micro" decision concerning how this total would be allocated to affected firms in each member state. Each member state took the initiative in proposing in its National Allocation Plan (NAP) total and in specifying the allocation to installations, but both aspects were subject to review by the commission. The allocation of the shortage to the EU15 resulted from the structure of the member-state commitments under the Kyoto Protocol.

In each trading period, the large emitters obtain trading permits from the NAPs and purchase EU and international trading credits as well. Each member state allocates allowances to each industrial sector. Since the electricity utility sector does not face severe non-EU international competition, most EU15 countries allocated the shortage to the power sector. The power plants account for a large amount of carbon emissions and face the largest regulation constraints, which could be uneven among EU countries. This is one reason why I focus on within-EU trade flow changes before going to the international carbon leakage effects.[2]

[2]Carbon leakage occurs when there is an increase in carbon dioxide emissions in one country as

The price of the permission per ton of carbon is determined by the market demand and supply. The trading price is equal across the EU. Excessive allowances will result in a low carbon price, and reduced emission abatement efforts (Newbery, 2009). Too few allowances will result in too high a carbon price (Hepburn, 2006). Since most of the allowances are currently given away freely, it could be viewed as endowments for each member country. Because of the mechanism of allocation and possible leakage, which is the effect of emissions increasing in countries or sectors that have weaker regulations; there is a potential pollution haven effect since the permits are distributed and traded among countries, even though the trade price is the same across the EU. It is possible that, within EU countries, there are countries with more stringent regulations that attained fewer quotas compared to what they could have attained, and weaker regulated countries that possess more.

One traditional way of environmental regulation is to add taxes on emitted pollutants. Similarly, a cap-trade scheme with purchased permission also raises the cost through increases of abatement costs. However, the possible outcomes of EU ETS are not clear. The freely allocated allowance is viewed as a windfall asset for manufacturers, the comparative advantage for those who have abundant emission quotas will increase. Additionally, some countries do have a very small proportion of allowances sold through auctions rather than given freely. Though the amount is limited, less than 5% in the first phase, and 10% in the second phase, they could have entirely opposite effects compared to the freely allocated allowances. The possibilities could be summarized in three main points: First, launching of EU ETS is a strict environmental policy that could result in disadvantage in international competition. Even if there is no shortage for other industries, 64% of companies responding to an October 2008 survey said they had average annual costs of monitoring and reporting of £26,000 and average annual verification costs of £9,000. Second, some industries

a result of an emissions reduction by a second country with a strict climate policy.

claim that the allocation is a windfall financial asset which could benefit their international competitiveness because in Phase I and Phase II, most allowances are given away freely. Regions will export goods that use locally abundant factors, that is, countries in the long-position may export more goods that emit more CO_2 within the EU. Third, carbon leakage may occur. External EU trading partners, those who are not constrained by EU ETS, could have larger emissions of carbon by producing more than before due to their comparative advantage.

3.3 Model Setup

This model is a 2×2 model based on Markusen (2002) with national exporting enterprises and HMNEs. Also, to study the effect of environmental regulation, I extended the model by changing the production factors to labor, capital and carbon emissions based on Copeland and Taylor (1994). The model incorporates two countries, country 1 and country 2. Both of them could produce two goods, x and y. Good y is homogenous and can be produced with constant returns by a competitive industry with only one production factor–labor, and will be used as numeraire. Producers for good x are differentiated. [3] The capital is mobile as FDI flows, thus the MNEs could adjust their allocations of capital between headquarters country and its affiliate abroad. Differentiated goods producers operate in a monopolistically competitive market. The output of both goods follows a Cobb-Douglas function. There are two kinds of firms in producing good x, one are national enterprises who can produce differentiated goods for the home market and also export them to a foreign country with transportation and tariff costs. The other kind are HMNEs that must have a plant in each country but cannot participate in exporting.

[3] Only regulated countries– EU ETS members have to pay for the carbon emission factors, thus we can view it as immobile.

The production function of numeraire good y is:

$$y_i = L_i, \quad (i = 1, 2, 3)$$

I assume country 1 is the numeraire, thus, $p_{y1} = w_{y1} = 1$.

Similarly, the production function of good x is also given by a Cobb-Douglas function. Assume all firms in both countries have the same technology term B, and let K_{xi}, S_{xi} and Z_{xi} stands for the quantities of capital, labor and emissions respectively. In country i, the production of good x is:

$$F_{xi} = B(K_{xi}^{\gamma} + L_{xi}^{\gamma})^{\frac{\alpha}{\gamma}} Z_{xi}^{1-\alpha}$$

α is the share of main factors in production and γ is the degree of substitutability between labor and capital. Even if all firms faces the same technology, they differ in fixed costs. If firms face environmental regulations, their abatement technologies have to use labor and capital to reduce emissions. If there is no regulation, following Copeland and Taylor (1994), one unit of production requires one unit of emission. That is the bound on the substitution possibility between other two factors and pollution inputs. The production function of good x can be written as:

$$F_{xi} = B^{\frac{1}{\alpha}} (K_{xi}^{\gamma} + L_{xi}^{\gamma})^{\frac{1}{\gamma}}$$

National enterprises maximize profits by choosing labor, capital and emission inputs. Under this case, let c_{xi} denote marginal production costs of differentiated good x in country i. The profit function of national enterprises firms are:

$$\pi_1^n = (p_{x1} - c_{x1})(x_{11} + x_{12}) - f_1^n$$

$$\pi_2^n = (p_{x2} - c_{x2})(x_{21} + x_{22}) - f_2^n$$

where $x_1^n = x_{11} + x_{12} = F(L_1^n, K_1^n, Z_1^n)$ and $x_2^n = x_{21} + x_{22} = F(L_2^n, K_2^n, Z_2^n)$. x_{11} stands for domestic sale of national enterprises in country 1, x_{12} denotes its exports to country 2. f_1^n denotes the fixed cost of entering the market for national enterprises.

The profit function for HMNEs is:

$$\pi_1^h = (p_{x1} - c_{x1})x_{11}^h + (p_{x2} - c_{x2})x_{12}^h - f_{11}^n - f_{12}^n$$

$$\pi_2^h = (p_{x1} - c_{x1})x_{21}^h + (p_{x2} - c_{x2})x_{22}^h - f_{21}^n - f_{22}^n$$

for $x_1^h = x_{11}^h + x_{12}^h = F(L_1^h, K_1^h, Z_1^h) + F(L_2^h, K_1^h, Z_2^h)$ and $x_2^h = x_{21}^h + x_{22}^h = F(L_1^h, K_2^h, Z_1^h) + F(L_2^h, K_2^h, Z_2^h)$. x_{ij}^h stands for the production in country j by firm whose headquarter is in country$i$. As mentioned before, capital is mobile with no transportation costs, HMNEs still rent labor from their home countries but the other two inputs, labor and emissions have to be purchased from the country in which the plant located.

On the demand side, I assume that consumers have a Cobb-Douglas utility function between goods x and good y. The utility function is constant elasticity of substitution (CES). Consumers in country i could buy goods form both domestic producers, the national enterprises, HMNEs headquarters and also imported goods from country j. As a reminder, national enterprises could export to a foreign country. HMNE's production by the headquarters only serve the domestic market. At the meantime, their productions in offshore firms only serves the foreign market. Besides benefits from consumption, consumers also face hazardous pollution caused by production of good x. Utility function is given as:

$$U_i = [n_1(x_{11}^n)^{\frac{\epsilon}{\epsilon-1}} + n_2(\frac{x_{21}^n}{t_{21}})^{\frac{\epsilon}{\epsilon-1}} + h_1(x_{11}^h)^{\frac{\epsilon}{\epsilon-1}} + h_2(x_{21}^h)^{\frac{\epsilon}{\epsilon-1}}]^{\frac{\epsilon-1}{\epsilon}\eta}[Y]^{1-\eta}$$
$$- \Phi(Z_1^n + Z_2^n + Z_1^h + Z_2^h)$$

The first component stands for domestic consumption of national enterprises, the second component stands for domestic consumption of export good from foreign national enterprises. The third term is domestic consumption from home HMNEs. The fourth term denotes the domestic consumption from foreign HMNEs. n_i and j_i are endogenous numbers of national enterprises and HMNEs in country i. t_{ij} is the gross trade cost of exporting good x from country j to i. The consumption of good y also includes both domestic y and imported y. The last term is the harm generated by pollution of all productions from both types of firms in both countries.

Following Bergstrand and Egger(2007), the gross trade cost is defined as:

$$t_{x_{ij}} = (1 + b_{x_{ij}})(1 + \tau_{x_{ij}})$$

where τ denotes a "natural" trade cost of the iceberg type, while b stands for the tariff rate.

Since free entry and exit is allowed, firms do not make profits and the income of consumers is only from wages, rents and emissions. The tariff revenue is redistributed in lump-sum payments by the government to consumers. If we assume country 1 imposes a cap-and-trade environmental regulation, the revenue collected R_z will also transfer to consumer through lump-sum payments. Thus, income can be written as:

$$I_1 = r_1K_1 + w_1L_1 + n_2b_{x_{21}}p_{x_2}^n x_{21}^n + R_z$$

$$I_2 = r_2K_2 + w_2L_2 + n_1b_{x_{12}}p_{x_1}^n x_{12}^n$$

Consumption in country 1 could be written as:

$$E_1 = n_1 p^n_{x_1} x^n_{11} + n_2 p^n_{x_2} x_{21} + h_1 p^h_{x_1} x^h_{11} + h_2 p^h_{x_1} x^h_{21} + p_{y_1} y_{11} + p_{y_2} y_{21}$$

Similarly, consumption in country 2 is:

$$E_2 = n_1 p^n_{x_1} x^n_{12} + n_2 p^n_{x_2} x_{22} + h_1 p^h_{x_2} x^h_{12} + h_2 p^h_{x_2} x^h_{22} + p_{y_1} y_{12} + p_{y_2} y_{22}$$

where $p^n_{x_i}$ stands for the price charged by producer in i for good x, $p^h_{x_1}$ is the price of good x which are produced within country 1. According to the property of Cobb-Douglas utility function, we can derive the expenditure for good x and good y:

$$X = \eta E / P_x$$

E is the income and P stands for the price index of all type of good x. The price index is:

$$P_x = [n_1 (p^n_{x_1})^\epsilon + n_2 (t_{x_{12}} p^n_{x_2})^\epsilon + h_1 (p_{x_{11}})^\epsilon + h_2 (p_{x_{21}})^\epsilon]^{\frac{1}{\epsilon}}$$

By using the price index, we can generate the demand function for each type of good x in terms of expenditure and price:

$$x^l_i = (p^l_{x_i})^{\epsilon-1} P_x^{-\epsilon} \eta E$$

Assuming consumers are price takers and global emissions are also given, taking the first order condition of utility function for different x, yields:

$$\frac{x^n_{11}}{x^n_{21}} = (\frac{p_{x_1}}{p_{x_2}})^{\epsilon-1} t^{-\epsilon} (1 - b_{21})^{\epsilon-1}$$

Then we can move to the maximization of profits for all firms. If we further assume that country 1 has cap-and-trade regulation with uniform freely allocated allowances s to all firms, then the profit function can be rewrite as:

$$\pi_1^n = p(q_1^n(L,K,Z))q_1^n(L,K,Z) - w_1 L_1^n - r_1 K_1^n - p_z(s - Z_1^n) - f_1^n$$

$$\pi_1^h = p(q_1 1^h(L_1, K_1, Z_1))q_1 1^h(L_2, K_1) + p(q_{12}^h(L,K,Z))q_{12}^h(L,K,Z)$$
$$- w_1 L_{11} - w_2 L_1 2 - r_1(K_{11} + K_{12}) - p_z(s - Z_{11}) - f_1^h - f_2^h$$

$$\pi_2^n = p(q_2^n(L,K,Z))q_2^n(L,K,Z) - w_2 L_2^n - r_2 K_2^n - f_2^n$$

$$\pi_2^h = p(q_2 1^h(L_1, K_2, Z_1))q_2 1^h(L_1, K_2, Z_1) + p(q_{22}^h(L,K,))q_{22}^h(L,K,)$$
$$- w_1 L_{21} - w_2 L_{22} - r_2(K_{21} + K_{22}) - p_z(s - Z_{21}) - f_1^h - f_2^h$$

In equilibrium, I assume no profit is earned by firms and all factors are fully employed. Under this case, the social welfare will be a function of total production and pollution. The complexity of the model introduces a high degree of nonlinearity. In Markusen(2002) and Bergstrand, Egger (2007), rather than giving an analytical solution, they provide numerical solution to the model by simulation. Choosing parameters and exogenous variables' values could be a problem for those kinds of simulation. Thus, in my work, I will conduct an empirical study to relate the model with econometric evidence.

3.4 Heterogenous Firms

In the previous section, I assume all firms face the same technological constraint, thus, the same marginal cost for production. In order to determine firms' entry and exit more precisely, I add heterogeneity to firms technology constraint. Assume each firm is endowed with productivity level $\phi \in (0, \infty)$ with higher ϕ as higher productivity. To simplify this complicated case, instead of using all production factor, I assume besides emissions, there is only one input, labor. Good x represents the only goods in the market.

$$U = [\int_{\phi \in G} (x_{11}^n)^{\frac{\epsilon}{1-\epsilon}} dG + \int_{\phi \in G} (\frac{x_{21}^n}{t_{21}})^{\frac{\epsilon}{1-\epsilon}} dG + \int_{\phi \in G} (x_{11}^h)^{\frac{\epsilon}{1-\epsilon}} dG + \int_{\phi \in G} (x_{21}^h)^{\frac{\epsilon}{1-\epsilon}} dG] - \Phi(Z)$$

Similarly, we can generate a demand function in terms of expenditure and price index:

$$X = E/P_X = E/[\int (p_{x_{11}}^n)^\epsilon + \int (t_{21} p_{x_{21}}^n)^\epsilon + \int (p_{x_{11}}^h)^\epsilon + \int (p_{x_{21}}^h)^\epsilon]^{\frac{1}{\epsilon}}$$

For each kind of good x, their demand functions could be written as:

$$x_i^l = (p_{x_i}^l)^{\epsilon-1} P_x^{-\epsilon} \eta E$$

The production of good x has two inputs, labor and emissions. Labor is mobile under this case, HMNEs only hire workers from their own country. Emission is "immobile", thus HMNEs' affiliates in non-regulated country do not need to pay for pollution. Like before, if there is no environmental regulation, one unit of output requires one unit of emission. The production functions are defined as, $i \in (11, 12, 22, 21)$ and $l \in (h, n)$:

$$x_i^l = \phi z^\alpha L^{1-\alpha}$$

$$x_i^l = \phi \phi^{\frac{\alpha}{1-\alpha}} L = \phi A L$$

Profit functions for national enterprises and HMNEs in regulated countries are:

$$\pi_1^n = p_1 q_1^n - w_1 L_1^n - f_1 - p_z(s - z_1^n)$$

$$\pi_1^h = p_1 q_{11}^h - w_1 L_1 - f_1 - p_z(s - z_{11}^h) + p_2 q_{12}^h - w_1 L_1 - f_2$$

Profit functions for non-regulated countries are:

$$\pi_2^n = p_2 q_2^n - w_2 L_2^n - f_2$$

$$\pi_2^h = p_1 q_{21}^h - w_2 L_2 - f_1 - p_z(s - z_{21}^h) + p_2 q_{22}^h - w_2 L_2 - f_2$$

Firm's optimal markup for non-regulated firms is:

$$p_i(\phi) = (\frac{\epsilon}{1-\epsilon} \phi A)^{-1}$$

Regulated firms have to substitute labor with emission in terms of α and relative price of emission p_z:

$$p_i(\phi) = (\frac{\epsilon}{1-\epsilon}\phi B)^{-1} \text{ where } B = \frac{\alpha^\alpha(1-\alpha)^{1-\alpha}}{p_z^\alpha}$$

From utility maximization, we can find the relationship between x_{11} and x_{21}:

$$\begin{aligned}\frac{x_{11}}{x_{21}} &= (\frac{p_1}{p_2})^{\epsilon-1}t^{-\epsilon}(1-b_{21})^{\epsilon-1} \\ &= (\frac{\phi_2 B}{\phi_1 A})^{\epsilon-1}t^{-\epsilon}(1-b_{21})^{\epsilon-1}\end{aligned}$$

A is larger than B, thus, for firms with same productivity, non-regulated firms produce more. Similarly, the emissions for a regulated firm are smaller than for a non-regulated firm. If both of them are under the same circumstance, wether regulated or not, the more efficient firm generates more emissions than the less efficient firm in total amount. The marginal cost can be obtained since the firm chooses the optimal combination of inputs so that the input price ratio equals the marginal rate of technical substitution:

$$c(q) = \frac{q}{\phi B}$$

Free entry and exit ensure:

$$f_1 \geq (\frac{\epsilon}{1-\epsilon}\phi B)^{-1}(x_{11}^n + x_{21}^n)$$

$$f_1 + f_2 \geq (\frac{\epsilon}{1-\epsilon}\phi B)^{-1}x_{11}^h + (\frac{\epsilon}{1-\epsilon}\phi B)x_{21}^h$$

The regulation will drive out some high efficient national enterprises under uniformly distributed allowances. It will also affect some of HMNEs since I assume they have to have plants in both countries. However, if HMNEs can relocate most of their resources or production to unregulated country, they will not be driven out of the market. But under the circumstance that allocation plans rather than uniformly distribution are applied, results could be different.

3.5 Empirical study

From the model above, in order to estimate the effect of EU ETS on FDI, we need to isolate the effect on HMNEs from national enterprises that export goods abroad. FDI flows change depends on firms' characteristics (productivity), wage of labor, rent of capital, revenue or payment after cap-and-trade emission regulation, prices of importing goods and price of domestic goods. Same as international trade, FDI also has inward and outward flows. Generally, inward FDI is treated as a substitute for imports, outward FDI as a substitute for exports. I will separate inward and outward flows into two parts when conducting my analysis.

The sample includes both regulated and non-regulated industry of all EU member countries before and after EU ETS. A dummy for regulation status for each industry in each country and year will reflect the impacts on the dependent variable, FDI flows. Besides all relevant variables mentioned in the last paragraph, fixed effects are also included in regressions, they are country × year dummy as well as industry dummies. The fixed effects panel regression in empirical studies could solve the possible endogeneity caused by unobserved variables and self-selections. The linear regression model is:

$$FDI^j_{its} = \beta_0 + \beta X_{its} + \gamma D + \delta R + \sigma V^j_{its} + \epsilon_{ijts} \quad j \in (inward, outward)$$

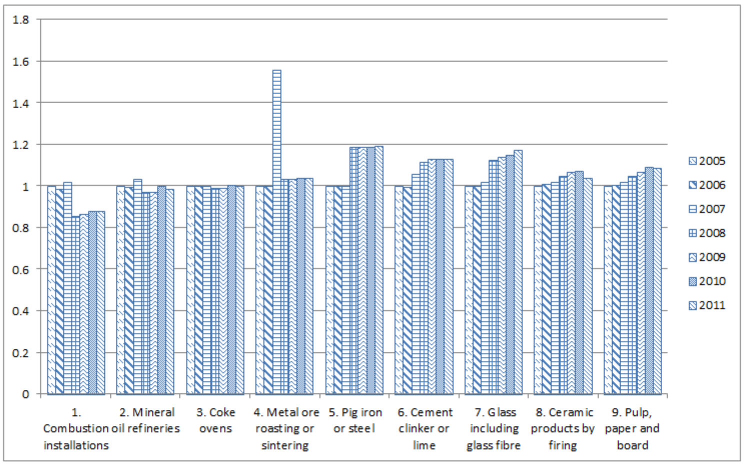
where X_{its} denotes main characteristics for country i in year t at industry s. It includes production index, domestic price index, import price index and wage rate for corresponding country, industry and year, as well as GDP and population. R stands for regulation status of EU ETS, if an industry in country i at year t is covered by EU ETS, $R = 1$. D stands for all fixed effects dummies mentioned above. V is the log value of international trade flows.

In the previous chapter, I show that international trade flows are significantly affected by EU ETS. That is, regulation increases imports and decreases exports for regulated industries. After partialling out countries' characteristics, such as GDP and population, FDI flows should have a negative relationship with international trade flows. The coefficient of R should reveal the real effects of EU ETS on FDI flows after controlling all those variables.

The data are an unbalanced annual panel from 2000 to 2012, that is 5 years before EU ETS and two phases of EU ETS since 2005. All EU countries are included. Countries joined EU ETS at different years. EU 15 were required to join EU ETS in 2005, while the rest of them joined EU ETS in 2007 and the following years. Moreover, not all industries are joined at the same time within a country. The FDI flows are obtained from OECD in Extraction of crude petroleum and natural resources, mining and quarrying, qgriculture and fishing, food products, textiles and wearing apparel, wood publishing and printing, refined petroleum & other treatments, rubber and plastic products, chemical products, medical precision and optical instruments,construction, metal product, office machinery and computers, motor vehicles, other transport equipments, manufacture of aircraft and spacecraft.

The allowance data are available from the Community International Transaction Log, version 13 (CITL v.13) provided by the European Environmental Agency (EEA). The data include ten sectors: combustion installations; mineral oil refineries; coke ovens; metal ore roasting sincerity; pig iron or steel; cement clinker or lime; glass including glass fiber; ceramic products by finery; pulp, paper and board and other activities which opted in. The last sector, "other activities opted in" was included to cover other installations opted in under Article 24 of the EU ETS Directive. In practice, the activity of an installation that is listed under this sector in the CITL is often not clear. Thus, I only focus on the nine sectors that are clearly defined. The amount of allowances for each sector is shown in Figure 1. The combustion installations take most of the total freely allocated allowances and experienced reductions in Phase II. Compared to combustion installation sector, other eight sectors have a relatively constant amount of allowances[4].

Figure 5: Allowances by year and sector



There are two categories for allocation data, one is freely allocated EU allowances (EUAs) and the other one is verified emissions. Information on verified emissions and freely allocated EUAs is presented for two different scopes: "Verified emissions (all installations)" and "Verified emissions (installations with emissions for 2008 until 2012)"; "Freely allocated EUAs" and "Freely allocated EUAs (installations with emissions for 2008 until 2012)".

All other data are obtained from Euro Stat. Intra-industry trade flow data are from Euro Stat, with 3-digit SITC classification format. The international trade flows are in aggregate level for the rest of world, and also separated as intra-EU trade and extra-EU trade to distinguish the regulated regions from unregulated regions based on the theoretical model in section III. Domestic price index, production index,

[4]The outlier for metal ore roasting or sintering sector in 2007 is because there were several more countries participating EU ETS in this sector since 2007 while the early members' allowances were not adjusted to fit the cap. Starting from 2008, the first year of Phase II, all allocated allowances were adjusted.

import price index and wage are all classified by NACE Revision 2, mainly on B and C classification. Because of confidential issues, part of those data are unavailable resulting in an unbalanced panel data.

Noticeably, those data are classified with different standards in defining industries. An important work is to merge them with a uniform standard to generate complete data. The currently available correspondence of NACE Revision 2 to SITC is far away from complete, so I generate a correspondence of all different industries or sector classification. They are listed in appendix.

Because of limitation of availability of FDI flows data, a gravity model cannot apply to this study. The international trade flows are separated into EU 25- extra, EU 25- intra, EU 15- extra and EU 15- intra to include into the linear regression.

The regression results are shown in table 12. From the table, I find that domestic production price index increases inward FDI but decrease outward FDI. It is straightforward since investment moves to more profitable country. The higher the domestic price, more investment from abroad. The wage index has negative relationship with inward FDI and positive relationship with outward FDI. This result also follows intuition and the theoretical model. Section I assumes that labor is immobile, thus a higher wage rate in home country will decrease inward FDI and slightly increase outward FDI to cheap labor countries.

The signs for trade flows are complicated. Both intra-EU imports and extra-EU imports decrease inward FDI, thus they are substitutes. However, extra-EU exports decrease outward FDI, while intra-EU exports increase outward FDI. One possible reason for this is, since the EU is a custom union, that the higher the value of intra-EU flows, the higher the productivity of the country is. For example, consider Germany and the United Kingdom compared to other EU members. They are likely to have more FDI flows in both directions than other EU countries. The production volume index is negative for both inward and outward flows. It means when taking

Table 12: Regression Results

	EU-25		EU-15	
	FDI Inwards	FDI Outward	FDI Inward	FDI Outward
EU-EXTRA log trade	-240.236	-234.034	678.984	-436.975
	(1236.69)	(555.49)	(2158.70)	(997.93)
Regulation Dummy	-2552.410	-1648.073	-2159.698	-603.929
	(2441.34)	(1250.05)	(2862.69)	(1638.37)
Production Index	4.022	5.532	-10.297	-19.726
	(42.67)	(13.33)	(21.53)	(22.41)
Wage Index	-28.691	-19.583	-16.394	17.874
	(54.89)	(25.06)	(40.74)	(39.33)
Production Price Index	29.992	-100.701	29.568	-116.213
	(112.99)	(78.00)	(114.70)	(72.78)
EU-INTRA log trade	-1105.656	-16.209	-1365.883	27.570
	(1037.32)	(643.60)	(1481.08)	(917.68)
R-sqr	0.595	0.795	0.585	0.837

* $p < 0.05$, ** $p < 0.01$,*** $p < 0.001$

out countries' characteristics by fixed effects, more domestic production decreases the flows of FDI. Since higher domestic production is a substitute of inward flows, and for domestic firms, it is profitable to produce within home country,rather than investing abroad.

The regulation status of EU ETS is negative for both FDI inward and outward flows. According to PHH, environmental regulation should increase FDI outwards flows but decrease FDI inward flows, that is the relocation of firms to unregulated countries. The empirical results I get are counter-intuitive here. From the model in section IV, for national enterprises, the output of a firm in regulated country is smaller than that for a firm with the same productivity but in an unregulated country. But for two different firms under same regulation, their output depends on their productivity. Moreover, a uniform distributed allowances under cap-and-trade scheme may drive out efficient firms, thus, not only inward FDI flows decrease, the decrease of endogenous numbers of HMNEs brings down outward FDI flows as well.

However, because of limitation and incomplete of data, none of those coefficients are significant.

3.6 Conclusion and Future Study

This chapter builds an FDI and international trade model by taking emissions as an input. It assumes endogenous entry and exit of firms so the firms could react to a new environmental regulation, specially EU ETS. This complicated nonlinear model implies that FDI flows depend on international trade flows, domestic price, production, import price, wage and rent. It provides sights for improving further traditional gravity model on studying of FDI flows. Moreover, heterogeneity in firm productivity is introduced into the model to further explain firm behavior, especially how the "cutoff" affects firm entry and exit. The results also highlight that the way allowances are distributed matters for firms behavior. In section V, I use cross-country cross-year unbalanced panel data to evaluate the impact of EU ETS on FDI flows by controlling not only for country, industry and year fixed effects, but also to include the relative industry level price index, such as wage, rent, import price and domestic price. The coefficients for all prices support the theoretical model. Also, international trade flows have different effects on FDI flows depending on whether they are intra-EU flows or extra-EU flows. The result shows that EU ETS decreases both inward and outward FDI flows. The decrease of FDI inward flows confirm PHH. And the decreases of outward FDI flows follow the theoretical model that domestic firms are driven out of the market.

Like other FDI or relocation study of PHH, this chapter does not find mathematically significant results either. Further study should focus on data. Since FDI, international trade flows, industrial level price indices and EU ETS regulations are classifications with different standards, through merging all datasets will definitely generate errors in sampling. Moreover, because of confidential issue, a large portion of FDI flows and price index data are missing, which results in an extreme imbalance of panel data. Detailed industry level data for key variables are also lacking. Unlike the first chapter of this thesis on international trade flows, which has complete data, the data available for FDI flows is far from good. Firm level datasets could also solve a part of the problem since it could capture more detail about firms' reactions in facing a new environmental regulation. However, firm level data could also be problematic because of randomness. Firm's market power could also influence accurate evaluation of environmental regulations.

Table 13: Matching between NACE Revision 2 and SITC 3-digit classification

NACE Revision2	Label	SITC 3- digit
B05	Mining of coal and lignite	321
B061	Extraction of crude petroleum	333
B062	Extraction of natural gas	343
B071	Mining of iron ores	281
B072	Mining of non-ferrous metal ores	283 284 285 286
B081	Quarrying of stone, sand and clay	273
B089	Mining and quarrying n.e.c.	278
C101	Processing and preserving of meat and production of meat products	17
C102	Processing and preserving of fish, crustaceans and molluscs	34 35
C103	Processing and preserving of fruit and vegetables	58 56
C1032	Manufacture of fruit and vegetable juice	59
C104	Manufacture of vegetable and animal oils and fats	411 222 421 431
C105	Manufacture of dairy products	022 023 024
C106	Manufacture of grain mill products, starches and starch products	48

Continued on next page

Table 13 – continued from previous page

NACE Revision2	Label	SITC 3- digit
C1081	Manufacture of sugar	61 62
C1082	Manufacture of cocoa, chocolate and sugar confectionery	72 73
C1083	Processing of tea and coffee	74 71
C1084	Manufacture of condiments and seasonings	75
C109	Manufacture of prepared animal feeds	81
C110	Manufacture of beverages	111 112
C12	Manufacture of tobacco products	122
C13	Manufacture of textiles	137 238
C14	Manufacture of wearing apparel	841 842 843 844 845
C15	Manufacture of leather and related products	613
C16	Manufacture of wood and products of wood and cork, except furniture;	634 635
	Manufacture of articles of straw and plaiting materials	
C171	Manufacture of pulp, paper and paperboard	641
C172	Manufacture of articles of paper and paperboard	642
C191	Manufacture of coke oven products	325
C192	Manufacture of refined petroleum products	334

Continued on next page

Table 13 – continued from previous page

NACE Revision2	Label	SITC 3- digit
C2012	Manufacture of dyes and pigments	532
C2013	Manufacture of other inorganic basic chemicals	524
C2015	Manufacture of fertilisers and nitrogen compounds	514 562
C2016	Manufacture of plastics in primary forms	571 572 573 574 575
C2017	Manufacture of synthetic rubber in primary forms	525 529
C202	Manufacture of pesticides and other agrochemical products	591
C203	Manufacture of paints, varnishes and similar coatings, printing ink and mastics	533
C2041	Manufacture of soap and detergents, cleaning and polishing preparations	554
C2042	Manufacture of perfumes and toilet preparations	553
C205	Manufacture of other chemical products	593
C206	Manufacture of man-made fibres	266 267
C21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	541 542
C221	Manufacture of rubber products	625

Continued on next page

Table 13 – continued from previous page

NACE Revision2	Label	SITC 3- digit
C222	Manufacture of plastics products	582 581
C231	Manufacture of glass and glass products	664 665
C232	Manufacture of refractory products	662
C233	Manufacture of clay building materials	661
C235	Manufacture of cement, lime and plaster	661
C241	Manufacture of basic iron and steel and of ferro-alloys	671
C242	Manufacture of tubes, pipes, hollow profiles and related fittings, of steel	677 678 679
C2442	Aluminium production	684
C2443	Lead, zinc and tin production	685
C2444	Copper production	682
C251	Manufacture of structural metal products	691
C252	Manufacture of tanks, reservoirs and containers of metal	692
C257	Manufacture of cutlery, tools and general hardware	696
C265	Manufacture of instruments and appliances for measuring, testing and navigation; watches and clocks	873 874

Continued on next page

Table 13 – continued from previous page

NACE Revision2	Label	SITC 3- digit
C267	Manufacture of optical instruments and photographic equipment	871
C268	Manufacture of magnetic and optical media	881 882 883
C27	Manufacture of electrical equipment	771 772 773 776 778
C2812	Manufacture of fluid power equipment	742
C2813	Manufacture of other pumps and compressors	743
C2814	Manufacture of other taps and valves	747
C2822	Manufacture of lifting and handling equipment	744
C2823	Manufacture of office machinery and equipment	751
	(except computers and peripheral equipment)	
C2824	Manufacture of power-driven hand tools	695
C283	Manufacture of agricultural and forestry machinery	727
C284	Manufacture of metal forming machinery and machine tools	733
C2891	Manufacture of machinery for metallurgy	737
C2893	Manufacture of machinery for food, beverage and tobacco processing	727
C2894	Manufacture of machinery for textile, apparel and leather production	724
C2895	Manufacture of machinery for paper and paperboard production	725

Continued on next page

Table 13 – continued from previous page

NACE Revision2	Label	SITC 3- digit
C29	Manufacture of motor vehicles, trailers and semi-trailers	781 782 783 784 786
C301	Building of ships and boats	793
C302	Manufacture of railway locomotives and rolling stock	791
C303	Manufacture of air and spacecraft and related machinery	792
C3092	Manufacture of bicycles and invalid carriages	785
C31	Manufacture of furniture	821
C321	Manufacture of jewellery, bijouterie and related articles	897
C322	Manufacture of musical instruments	899

CHAPTER IV

HOW MULTI-LATERAL ENVIRONMENTAL AGREEMENTS AFFECT MEMBER COUNTRIES' BILATERAL TRADE FLOWS AFTER ADJUSTMENT OF TRADE AGREEMENTS AND ENDOGENEITY

4.1 Introduction

In the past few decades many countries realized the importance of environmental protection and sustainable development. Various environmental regulations have been adopted in order to limit the emission of pollutants and to protect the environment. As a result of increasing abatement cost for polluting industries, the pollution haven effect states that stricter environmental regulations may drive production to countries with less stringent environmental regulations. It is also known that lax environmental regulation may increase comparative advantage in polluting industries.

Much research effort has been focused on examining the pollution haven effect, both theoretically and empirically. Pethic (1976), Siebert (1977), McGuire (1982), Markusen (1999), Ulph (1999), and Millimet and List (2004) showed environmental regulations harm international trade. Walter (1982), Pearson (1985, 1987), Leonard (1988), and Taylor (2005) showed stringent environmental regulations could also decrease foreign direct investment. The existing studies use various ways to measure the stringency of environmental regulations. Ederington and Minier (2003) use environmental abatement cost as the measurement of the stringiness of regulations and treat it as endogenous in the U.S. from 1978 to 1992. Levinson and Taylor (2008) developed a theoretical model and test it empirically to examine the effect of environmental regulations on trade flows between the U.S., Canada, and Mexico, for 130 manufacturing industries from 1977 to 1986 with an instrument variable weighted by state characteristics.

Yet none of these traditional approaches examine or take into account the surge of voluntary multinational or international environmental agreements (MEA or IEA). An MEA is considered to be a legally binding agreement among several countries related to the environment. While environmental treaties date back to the end of the 19th century, the vast majority of MEAs have been adopted since the 1972 United Nations Conference on the Human Environment (UNCHE), often referred to as the Stockholm Conference. Indeed, UNCHE was a watershed event that helped launch the last 30 years of increasingly intensive treaty-making in the area of international environmental law as well as much activity within national governments. Adopted by all 113 countries present at the Stockholm Conference, the Stockholm Declaration was the first universal document of importance on environmental matters. It placed environmental issues squarely on the international scene. After 1972, the number of MEAs has risen tremendously. Among others, because of the ratification of the Montreal Protocol (1989), the number of MEA memberships has also increased.

Signing an MEA could eliminate the disadvantage in international competition caused by unilaterally imposed more stringent environmental regulations. Egger (2014) also shows that the numbers of MEAs are correlated with trade liberalization. Moreover, voluntary participation in MEAs is similar to trade liberalization realized by free trade agreements (FTA). When a country makes a decision whether to engage in a multilateral trade or environmental agreements, it will compare costs and benefits that depend not only on bilateral economic development, but also on bilateral political issues. According to previous studies, we know that countries tend to have an FTA if they are closer and similar in economy size. For environmental agreements, we can assume the same situations.

Over the past 40 years, the gravity equation has been the most widely used empirical model to study the ex post effects of trade related policies such as FTAs and customs unions on bilateral trade flows. The gravity equation is typically used to explain cross-sectional variation in country pairs' trade flows in term of countries' incomes, bilateral distance, common language, common borders, and for the presence or absences of an FTA [Trefler (1993), Anderson and Yotov (2009), Baier and Bergstrand (2004), (2007), Baier, Bergstrand, and Feng (2013), Cheng and Wall (2005), Anderson and van Wincoop (2003), Egger and Greenaway (2008)]. However, simply applying dummy variables in a gravity equation to estimate the effects of MEAs or FTAs could be problematic due to endogeneity, the voluntary participation on FTAs or MEAs. Some econometric tool could deal with this problem such as using panel data with fixed effects, using matching econometrics and Diff-in-diff (DID).

Several recent studies estimating the effects of MEAs on bilateral trade flows take endogeneity into account. Aichele and Felbermayr (2013) investigate the Kyoto Protocol's effects on international trade flows using matched pairs estimation dealing with self-selection in Kyoto Commitments. Their regression includes all gravity variables as well as FTAs with a DID model and shows a significant negative effect of Kyoto Commitments on exports. Aichele and Felbermayr (2011) derive a gravity equation for the carbon content of trade and suggests that Kyoto commitment on average leads to increased imports in committed countries. However, most of their work focuses on environment regulation stringency within a country or on a single multi-lateral environmental agreements (Kyoto Protocol, Aichele and Felbermayr (2011), (2012), (2013).

This chapter estimates the effects of MEAs on international trade flows using the gravity equation and controlling for international trade agreements at the same time as well. As mentioned above, if MEAs are endogeneous, cross-sectional empirical estimates of the effects of MEAs on trade flows would be biased. We follow Baier and Bergstrand (2007) and estimate the effects of MEAs on imports by using a panel of cross-section time-series data at five year intervals from 1965 to 2005 for 757 pairs of trade partners (184 importer countries and 242 exporter countries).

This chapter is distinguished from other papers on environmental regulations in several aspects. First, the basis of our MEA data is obtained from the International Environmental Agreements (IEA) Database Project by Ronald B. Mitchell and the IEA Database Project, 2002-2014. This truly systematic, comprehensive and up to date list (i.e., the population) of MEAs include not only the agreements that counter the pollution but also those that aim to preserve the ecology and species. Our work is the first investigation on trade flows with comprehensive MEAs data rather than national environmental regulation or single multinational environmental agreement. Second, by applying the panel cross sectional time series data, we solve the endogeneity of FTAs as well as MEAs. Furthermore, we separate the type of FTAs to capture the effects of trade liberalization rather than stick with a single dummy. In addition, we keep track of the total number of MEAs, MEAs with different subjects adn those with the same lineage. This provides us more accurate estimation for the effects of MEAs on international trade flows. We can further expand our results by estimating the effect on international trade flows with numbers of MEAs broken by different subjects that the agreement covers.

The empirical results in this chapter suggest several important conclusions. First, we found MEAs have a significant negative effect on imports, while FTAs have a significant positive effect. Those effects are consistent across various empirical specifications (including year fixed effects, country fixed effects, reporter by partner fixed effects, etc.). Traditional estimates of the MEAs on international trade flows by using cross-section gravity equation is biased. It overestimated the negative effect of MEAs. The second important finding in this chapter is that the simultaneous absence of FTAs and MEAs increases the bilateral international trade a lot in magnitude and significantly. This could be well explained by the self-selection of FTAs and MEAs.

The chapter is outlined as the following: Section 2 presents a traditional cross-section gravity equation as well as our empirical model with panel regressions and various fixed and time effects. In the section 3, the data used in this chapter are introduced. Section 4 discusses the results and compares different results. We also provide the possible explanations for potential bias. Section 5 concludes.

4.2 Econometric Model

The most commonly way to estimate international trade is to use gravity equation:

$$\begin{aligned} X_{ij} = \beta_0 (GDP_i)^{\beta_1} (GDP_j)^{\beta_2} (DIST_{ij})^{\beta_3} \exp(\beta_4 Lang_{ij}) \\ \exp(\beta_5 (ADJ_{ij}) \exp(\beta_6 (FTA_{ij})) \exp(\beta_7 (IEA_{ij}))\epsilon_{ij} \quad (2) \end{aligned}$$

where X_{ij} is the imports from country i to country j, or we call trade flows from exporter j to importer i. GDP stands for the gross domestic product in both country, importer and exporter. $X_(ij)$, GDP_i and GDP_j should be adjusted to 2005 price level. $DIST_{ij}$, $LANG_{ij}$ and ADJ_{ij} are gravity variables, standing for the distance between the economic centers of countries i and j, whether country i and country j share a common language (value 1 is yes and 0 otherwise) and whether country i and country j share a common land border (value 1 is yes and 0 otherwise).

In order to evaluate the effect of international environmental agreements accurately, we first take the free trade agreements into account. FTA_{ij} is a binary variable assuming the value 1 if country i and j have a free trade agreement and 0 otherwise. Similarly, IEA_{ij} is also a binary variable assumed to be 1 if country pair ij has international environmental agreements between them.

The most general estimation method is to take log on both side of gravity equation, which is also called cross-section gravity equation. The cross-section estimations try to find the average treatment effect which refers to the difference in trade flow between a pair-country whether they have an FTA and/or IEA. In this chapter, we also apply a cross-section model as one of our benchmarks. It is obvious that, if the choices of FTA and/or IEA is correlated with some unobserved factors, i.e. the error term, there will be some bias generated. Anderson and van Wincoop (2003) claim that ignoring pricing in the cross-section gravity equation results in bias. Suggested by them, a computationally easier method to capture pricing terms is to use country fixed effect. Considering the pricing factor not only changes cross countries but also time, it seems that country fixed effect by year will lead to consistent estimations.

Even after taking pricing factor into account by using country fixed effect, we only fix endogeneity caused by prices. There are numerous arguments addressed on how the other unobserved heterogeneity in trade flow determinants affect FTA. One of the most acceptable view is self-selection. Domestic policies on tariffs, competition and antitrust rules, anti-dumping rules and environmental regulations may have a positive relationship with the formation for FTAs since FTAs enhance trade liberalization without relaxing domestic regulations.

Similar issues–self-selection of IEAs and the interactions between the FTAs and IEAs– are more complicated. The self-selection into IEAs depends on economic size and economic growth. Also, Rose and Spiegel (2009) claim that signing environmental agreements positively affects cross asset holding. Egger et al. (2011) show that the numbers of IEAs are also affected by the trade liberalization, i.e. FTAs.

Our main method is to estimate IEA treatment effects using panel data in this work. We construct panel data from 1965 to 2005 of trade flows, bilateral trade agreements and international environmental agreements as well as gravity covariates.

The model can be expressed as:

$$X_{ijt} = \beta_0(GDP_{it})^{\beta_1}(GDP_{jt})^{\beta_2}(DIST_{ij})^(\beta_3)\exp(\beta_4(Lang_{ij})$$
$$\exp(\beta_5 ADJ_{ij})\exp(\beta_6 FTA_{ijt})\exp(\beta_7 IEA_{ijt})\epsilon_{ijt} \quad (3)$$

After taking log on both side of the equation, we have:

$$\ln X_{ijt} = \beta_0 + \beta_1\ln(GDP_{it}) + \beta_2\ln(GDP_{jt}) + \beta_3\ln(DIST_{ij}) + \beta_4 Lang_{ij}$$
$$+ \beta_5(ADJ)_{ij} + \beta_6(FTA_{ijt}) + \beta_7(IEA_{ijt}) + \epsilon_{ijt} \quad (4)$$

We provide several different estimations, an estimation with the model above without bilateral fixed effects or time dummies as our benchmark for panel regression, then we add time dummies only to our models. In order to adjust for unobserved time-invariant heterogeneity, we add country-pair fixed dummies as well. As mentioned above, the numbers of IEAs are affected by countries' trade liberalizations. Based on the type of FTAs (Type I stands for partial liberalization, i.e. one-way and two-way preferential trade agreements. Type II is FTAs and Type III includes customs union, common market, and economic union.), we generate interactions for FTAs and IEAs. Based on the previous experience studies and observations, we could expect FTAs will increase international trade flows. While the effects of MEAs should be negative based on pollution haven hypothesis. This discussion is very straight forward, for instance, two countries have agreements on marine species protection, trade flows within them on fishery should decrease. Similarly, if they engage in pollution regulations(agreements), bilateral trade flows between them on dirty products will reduce as a result of increase in abatement cost due to the stringent environmental regulation.

4.3 Data

The data we used consist of four parts: bilateral trade flows, free trade agreements, gravity variables, and multi-lateral environmental agreements.

The trade flow data are an aggregation of trade flows from the UN Comtrade database, using the 5-digit SITC revision 1 data as the starting point as it provides the longest possible time series. In this chapter, we use five-year window data from 1965 to 2005 for all potential trade partners (zero trade flows are excluded). The reason that we use every five-year data instead of annually data is that the policies, such as FTAs and IEAs do not change that frequently (Anderson and Yotov (2012) working paper). It will provide us a clearer result of how the environmental policies and trade agreements affect international trade. All trade flow data are scaled by GDP deflators to generate real trade flows.

As for the economic determinants of MEA and FTA membership, we include the GDP as a measure of a country's economic mass. Nominal GDPs are from the World Bank's World Development Indicators (2005) and scaled by the GDP deflator (2005) as well. Variables required for gravity equation such as geographical distance, adjacency, or common language are from a data set made publicly available by CEPII.

The trade agreement data are obtained from Baier and Bergstrand (2007) who compiled and maintain the Economic Integration Agreements Database. They classified integration agreements following Lawrence (1996) and Frankel (1997). The original data resource is at www.nd.edu/ jbergstr. In Baier, Bergstrand, and Mariutto (2014) and Baier and Bergstrand (2007) when the presences of FTAs are examined, only the full FTAs and customs unions are included. But in our work, all types of free trade agreements are considered.

MEA data are obtained from International Environmental Agreements (IEA) Database Project. They include multilateral and bilateral environmental agreements since 1857. All the agreements are recorded with signature date, agreement titles, membership, and agreement type by topic covered, lineage and sequences. We create a dummy variable for each active environmental agreements between each pair of countries according to the membership and year. We also create a count for each pair of countries by year to record the number of MEAs the pair shares. The counts for each subject are also generated to evaluate international trade flows by the different type (agreements[1], amendments[2], other modification[3] and protocol[4]) or subject(energy, freshwater resources, habitat, ocean, pollution, species and weapons and environment) of an MEA. All the counts can be adjusted by their lineages, as some agreements are updated and amended over time in order to avoid duplication of counts. In this chapter we mainly focus on the presences of MEAs by using an MEA dummy to indicate a country pair shares an agreement.

Table 14 listed the summary of statistics. There are total 94,808 observations with 29053 pairs of trade partners. Since the time period we chose to cover is from 1965-2005 every five years, we have unbalanced panel data. 17,053 observations have the IEA value equal to 0, while there are as many as 382 multi-lateral environmental agreements/protocol between France and Germany. United States have 240 MEAs with United Kingdom at 2005. Table 16 shows the percentile of the numbers of environmental agreements. Our data show the same results as in Egger et al (2011) that countries in Europe engaged in more MEAs than Africa or Asia countries. Figure 6 illustrates the numbers of MEAs within U.S and its major trade partner countries: Canada, Mexico, Germany, Unite Kingdom, China and Japan. We could observe a booming of the numbers of environmental agreements after 1980s. Similarly, Figure 7 shows the numbers of MEAs within China and several major trade partners including Canada, Mexico, India, Japan, United Kingdom and Germany.

[1] "Agreement" includes Accord, Act-Agreement, Act-Commission, Act-Treaty, Acuerdo, Adjustment, Agreement, Arrangement-Agreement, Articles of Association, Charter-Agreement, Constitution, Convencion, Convenio, Convention, Convenzione, Covenant, Exchange of Letters Constituting An Agreement, Exchange of Notes Constituting An Agreement, Grant Agreement, Instrument, Interim Agreement, Interim Arrangement, Interim Convention, Loan Agreement, Provisional Understanding, Statute, Statute-Commission, Supplementary Treaty, Tratado, Treaty.

[2] Amendment Agreement-Amendment; Amendment; Arrangement-Amendment; Extension

[3] "Other Modification" include Denunciation; Exchange of Letters Modifying an Agreement; Exchange of Notes Modifying an Agreement; Proces-Verbal

[4] Optional Protocol, Protocol, Protocole, Protocolo, Supplemental Agreement, Supplementary Agreement, Supplementary Arrangement, Supplementary Protocol

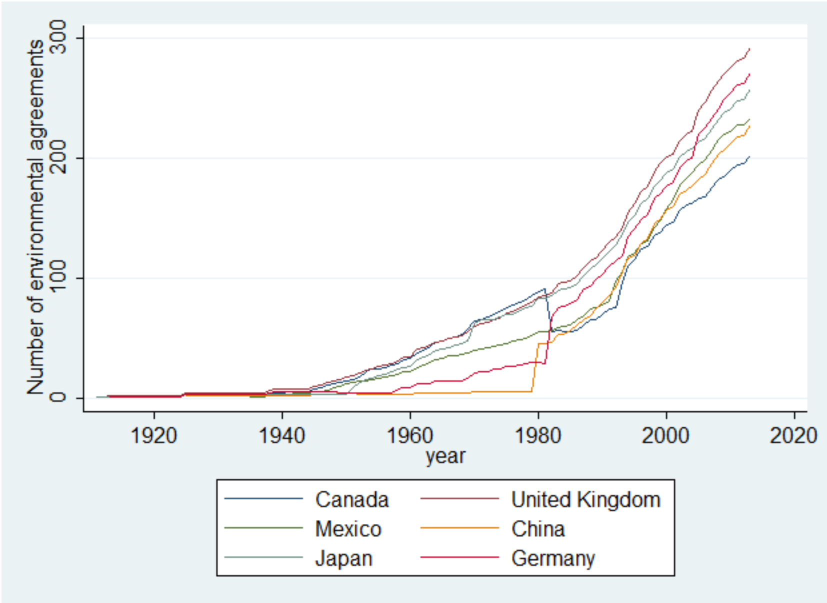
Table 14: Summary Statistics

Variable	**No. of Obser.**	**Mean**	**Std. Dev.**	**Min**	**Max**
Year	94,808	1,990.202	12.61805	1965	2005
Imports Flows	94,808	1.34E+08	1.39E+09	1	1.73E+11
No. of MEAs	94,808	34.86733	47.69225	0	382
No. of FTAs	81,730	0.4769	1.046069	0	6

Table 15: Types of FTAs

Type of trade agreements	**Freqency**	**Percent**	**Cum.**
0	61,392	75.12	75.12
1	11,597	14.19	89.31
2	2,896	3.54	92.85
3	3,378	4.13	96.98
4	1,227	1.5	98.48
5	894	1.09	99.58
6	346	0.42	100
Total	81,730	100	

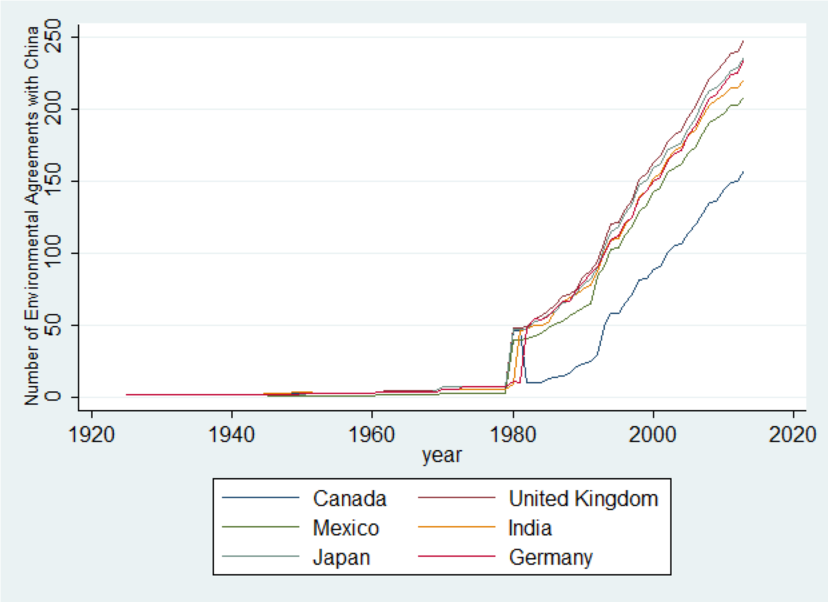
Figure 6: Numbers of MEAs within U.S and Tts Major Trade Partner



In this chapter, we focus more on taking dummy for MEAs as we are looking for the effects of presence of MEAs. But we also do some analysis on the numbers of environmental agreements. Noticeably, any consideration of the numbers of MEAs should be very careful since the weights or the effects of an agreement or a protocol with different subjects fluctuate.

According to Scott and Bergstrand (2007)'s data for trade agreements, our data has 13078 missing value, 61,309 with none trade agreements in any form among them. Type 1 and 2 stands for one-way and two-way preferential trade agreements (where preferential denotes only partial liberalization, not free trade). Type 3, Type 4, Type 5 and Type 6 stand for FTAs, customs union, common market, or economic union. The decomposition is provided in table 15.

Figure 7: Numbers of MEAs within China and Its Major Trade Partner



4.4 Results

4.4.1 FTAs dummy and IEAs dummy

We start our regression with cross-section OLS in table 17, which is also our benchmark. The first column follows the gravity equation that evaluates the effects of FTAs. In this stage, we stick to FTA dummy, that if there existing any trade agreements, it equals 1, otherwise it is 0. The result shows FTA will significantly increase

Table 16: Number of MEAs by percentile

Number of Environmental Agreements	Freqency	Percent	Cum.
0	17053	17.99	17.99
1–5	18951	19.98	37.98
6–15	14194	14.98	52.95
16-50	21215	22.37	75.32
51–100	14115	14.91	90.21
100–200	8280	8.78	98.95
200+	980	0.92	100
Total	94808	100	

bilateral trade by 64.9% for country-pair. In the column 2, we apply the same model but with IEA dummy only. As expected, we find that IEAs decrease bilateral trade by 1.096 log point. This result is also significant at 95% level. We take both IEA and FTA into account in column 3, which gives us a similar result, the FTA effect is 56.3% and the negative effect of IEA is 93.7%.

Table 17: OLS Cross-section Results

Variable	1	2	3	4	5	6	7	8	9	10
Ln GDP reporter	0.692***	0.699***	0.705***	0.701***	0.706***	0.923***	0.923***	0.929***	0.929***	0.932***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Ln GDP partner	0.886***	0.948***	0.906***	0.883***	0.901***	1.128***	1.180***	1.138***	1.121***	1.134***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
FTA dummy	0.649***		0.563***		-0.736***	0.611***		0.559***		-1.085***
	(0.02)		(0.02)		(0.08)	(0.02)		(0.02)		(0.07)
MEA dummy		-1.096***	-0.937***		-1.507***		-0.744***	-0.593***		-1.313***
		(0.04)	(0.04)		(0.05)		(0.04)	(0.04)		(0.05)
FTA only				-0.059					-0.591***	
				(0.06)					(0.06)	
MEA only				-0.816***					-0.806***	
				(0.02)					(0.02)	
MEA by FTA					1.415***					1.791***
					(0.08)					(0.07)
Country Fixed Effects	No	No	No	No	No	No	No	No	No	No
Year Fixed Effects	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes
R-sqr	0.565	0.565	0.568	0.568	0.569	0.643	0.642	0.645	0.647	0.647

* $p < 0.05$, ** $p < 0.01$, ***$p < 0.001$

In order to further understand the interaction between IEA and FTA, we use two different ways. We generate dummy IEAonly if the bilateral countries only have environmental agreements between them but no trade agreements. The dummy EIAonly is 1 if the bilateral countries only have trade agreements but no environmental agreements. If both agreements exist between importer and exporter, then the interaction of FTA and IEA will be 1. Results are listed in the column 4. Because of colinearity, the coefficient for interaction of FTA and IEA is omitted. The result implies that country-pairs with only trade agreements but no environmental agreements have 0.059 log points less trade flows than the country-pairs with both, also country-pairs with only environmental agreements but no trade agreements have 81.9 log points less trade flows than the country-pairs with both. EIAonly dummy is not significant while IEAonly dummy is significant at 95% level.

This result presents a very interesting phenomenon. Assuming that environmental agreements are irrelevant to free trade agreements, the presences of FTAs will increase bilateral trade while the presence of MEAs decrease bilateral trade flow as we discussed in section 2, we would expect that country-pair with only trade agreements should have largest amount of trade flows (partial out other effects that influence trade),followed by the country-pairs with environmental agreements and trade agreements. Country-pairs with only environmental agreements but no trade agreements should have smallest scale of international trade. However our results show that country-pairs with both agreements should have larger trade flows than have only one kind of agreements or nothing. It provides us an evidence that, countries with more trade flows may be more likely to sign agreements with each other. This is quite reasonable if we imagine two countries with large bilateral trade flows and free trade agreements, to avoid being the "pollution haven" of the other and to protect the comparative advantages, the social welfare would increase if both sign environmental agreements.

The second way to capture the interaction between trade agreements and environmental agreements is to keep the original dummy variables for trade and environmental agreements, then add the interaction of them. Results are presented in column 5. It suggests the same result in column 4. Country-pairs with both two kinds of agreements have the largest volume of trade. All the OLS results are very consistent, however, OLS results could be problematic due to the endogeneity caused by the pricing and self-selection that we discussed above.

In table 17 we also list the same regression results for FTA, IEA and both with year dummies in column (5)-(10). The magnitude of coefficients for FTAs and IEAs decrease. In the current stage, we consider only the average treatment effect of signing IEA with unobservable variables changing in every five years. After we taking out the year fixed effect, the FTA effects decrease from 64.9% to 61.1%, while IEAs effects change from 109.6% to 74.4%. Without interaction of FTAs and IEAs, IEAs decrease international trade more than it is increased by trade agreements. After adding the interaction terms (the two ways described above), having FTAs and IEAs simultaneously increases international trade the most. The year fixed effect model generally gives us the similar results and same trend as OLS regression.

Table 18: Panel Regression Results with Country Fixed Effects

Variable	1	2	3	4	5	6	7	8	9	10
Ln GDP reporter	0.593***	0.602***	0.595***	0.595***	0.594***	0.814***	0.806***	0.822***	0.824***	0.822***
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
Ln GDP partner	0.511***	0.545***	0.518***	0.523***	0.518***	0.669***	0.693***	0.681***	0.686***	0.681***
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
FTA dummy	0.502***		0.492***		0.464***	0.524***		0.513***		0.470***
	(0.02)		(0.02)		(0.10)	(0.02)		(0.02)		(0.10)
MEA dummy		-0.385***	-0.309***		-0.317***		-0.417***	-0.344***		-0.355***
		(0.05)	(0.05)		(0.06)		(0.05)	(0.05)		(0.06)
MEA only				-0.811***					-0.854***	
				(0.09)					(0.09)	
MEA FTA both presence				-0.344***					-0.362***	
				(0.09)					(0.09)	
MEA by FTA					0.029					0.045
					(0.10)					(0.10)
Country Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effect	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes
R-sqr	0.719	0.717	0.719	0.719	0.719	0.719	0.718	0.719	0.719	0.719

* $p < 0.05$, ** $p < 0.01$, ***$p < 0.001$

To capture the unobservable variables that affect countries choices on FTAs and IEAs as well as prices, we added the countries fixed effect in table 18, column (1) – (5). The results are similar with OLS regression except the magnitude getting smaller. The FTAs increases international trade by 0.464 and IEAs decrease trade flows by 0.309. However, after including interaction terms for both agreements, the presence of both trade agreements and environmental agreements reduces trade flows. In column 4, the EIAonly is omitted due to the colinearity. FTAs within bilateral countries increase trade volume the most by 0.464. Having both kinds of agreements increase international trade by 0.161. IEAs decreases trade volume by 0.327. These changes show the inconsistency of the OLS regressions. Then we regress year dummies and country dummies simultaneously, results are reported in table 5 column (6) – (10).

4.4.2 Panel Regressions: Fixed effects model

Then we move to panel regressions. We applied both fixed effects and random effects. Results are reported in table 19 and table 20 correspondingly. Columns (1) to columns (5) include no year fixed effects while (6) to (10) have year fixed effects in regression as we did above. According to the discussion above, the fixed effects model is more proper than the random effects model. The reason is that endogeneity bias except the pricing terms is unobserved time-invariant heterogeneity. For example, the social benefits interaction, political issues and competitions between the importer and exporter may simultaneously influence the presence of FTA, IEA and the volume of trade. Random effects model assuming that unobservable terms are irrelevant to the choices of FTA or IEA, which is less plausible. Moreover, Egger (2000) shows that using bilateral-pair or country specific fixed effect in gravity model is more reasonable than random effects model. Our results imply that a random effects model generates quite similar results as OLS regression. This method may not adjust endogeneity bias sufficiently. Within the panel regression, we also add year dummy to adjust the pricing change over years. The random effects model suggests the incremental trade volume caused by trade agreements is smaller than the reduction as a result of environmental agreements.

Table 19: Panel Regression Results with Fixed Effects

Variable	1	2	3	4	5	6	7	8	9	10
Ln GDP reporter	0.683***	0.687***	0.686***	0.684***	0.686***	0.885***	0.895***	0.899***	0.895***	0.898***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Ln GDP partner	0.538***	0.554***	0.550***	0.537***	0.550***	0.680***	0.702***	0.699***	0.686***	0.700***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
FTA dummy	0.097***		0.070*		-0.069	0.136***		0.110***		-0.099
	(0.03)		(0.03)		(0.10)	(0.03)		(0.03)		(0.10)
MEA dummy		-0.526***	-0.514***		-0.552***		-0.554***	-0.537***		-0.594***
		(0.05)	(0.05)		(0.05)		(0.05)	(0.05)		(0.05)
MEA only				-0.487***					-0.499***	
				(0.09)					(0.09)	
MEA FTA both				-0.314***					-0.283**	
				(0.09)					(0.09)	
MEA by FTA					0.143					0.216*
					(0.10)					(0.10)
Year Fixed Effect	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes
R-sqr	0.526	0.527	0.527	0.527	0.527	0.528	0.529	0.529	0.529	0.529

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 20: Panel Regression with Random Effects

Variable	1	2	3	4	5	6	7	8	9	10
Ln GDP reporter	0.537***	0.546***	0.547***	0.543***	0.546***	0.896***	0.900***	0.904***	0.902***	0.905***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Ln GDP partner	0.739***	0.769***	0.751***	0.739***	0.751***	1.079***	1.113***	1.089***	1.080***	1.089***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
FTA dummy	0.311***		0.265***		-0.054	0.423***		0.377***		-0.236**
	(0.02)		(0.02)		(0.08)	(0.02)		(0.02)		(0.08)
MEA dummy		-0.709***	-0.656***		-0.761***		-0.697***	-0.617***		-0.825***
		(0.04)	(0.04)		(0.05)		(0.04)	(0.04)		(0.05)
MEA only				0.321***					0.084	
				(0.07)					(0.07)	
FTA only				-0.382***					-0.501***	
				(0.02)					(0.02)	
MEA by FTA					0.340***					0.654***
					(0.08)					(0.08)
Year Fixed Effect	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes

* $p < 0.05$, ** $p < 0.01$,*** $p < 0.001$

Our fixed effect panel regression verifies that ignoring the endogeneity of bilateral countries characteristics overestimate the effects of FTAs and IEAs. By applying fixed effect panel regression, the positive effects of FTAs is 0.07 while the negative effects EIAs is 0.526. After adding year dummies, the coefficient of FTA is 0.11 and the coefficient for IEA dummy is -0.536. The adjustment of endogeneity provides us a convincing result that isolate the effects of trade agreements and environmental agreements. Comparing the situation with trade agreements only, having EIAs and FTAs simultaneously decrease international trade by 0.314, with only EIAs decreases trade volume by 0.487.

The last method that we are using to address the endogeneity is to add importer by year and exporter by year fixed effect with panel regressions. Results are listed in table 21. We still have significant and positive result for FTAs at 16%. The negative effect of EIAs is 16% but insignificant under each cases. The gravity variables are insignificant either since taking too many kinds of fixed effects. For example, importer by year and exporter by year fixed effects capture the real GDP of the importer and exporter. The bilateral country fixed effects capture the distances and other unobservable characteristics between trade partners. Thus, this result is less convincing than the panel regression with only bilateral countries fixed effects. From the summary statistics, we notice that some bilateral countries have been keeping some environmental agreements among them for decades. But the numbers of them increased sharply in 1980s. In order to further specify the effects of environmental agreements on international trade flows, we use log value of the numbers of environmental agreements to examine the influences by panel regressions with year fixed effects model. Results are reported in table 22. We also find significant negative effects of environmental agreements. The number of MEA increases by 1% will decrease bilateral trade flows by 7.5%. The FTA effects decreases to 10% comparing to previous results. One possible explanation is the multi-colinearity of FTA and

Table 21: Country by Year Fixed Effects Results

Variable	1	2	3	4	5
FTA dummy	0.147***		0.147***		-0.060
	(0.03)		(0.03)		(0.10)
MEA dummy		-0.025	-0.019		-0.081
		(0.08)	(0.08)		(0.09)
FTA only				0.054	
				(0.10)	
MEA FTA both				0.146***	
				(0.03)	
MEA by FTA					0.215*
					(0.10)
Country Fixed Effects	No	No	No	No	No
Year Fixed Effects	No	No	No	No	No
Country by Year FE	Yes	Yes	Yes	Yes	Yes
R-sqr	0.610	0.610	0.610	0.610	0.610

* $p < 0.05$, ** $p < 0.01$, ***$p < 0.001$

numbers of environmental agreements.

4.4.3 Categorization of different trade agreements

As described above, we could separate our trade agreements into four categories: trade agreements that include both partial trade agreements and free trade agreements, customs union, common market and economic union. We conduct same regressions with and without interactions of IEAs and FTAs as before. Table 23 applies OLS regression with and without year and country fixed effects. Column 1 stands for the OLS regression only for FTAs. Then we include them simultaneously in column 2 and add interactions terms in column 3. Column (4)-(6) follow the same pattern but year effects are included. Column (6) to (8) contain both year and country fixed effects. Table 24 presents panel fixed effect regressions with and without year fixed effects. We can still observe the severe bias of OLS regressions, even after adjustment with year or countries are applied. We find that customs union increases bilateral international trade the most comparing to trade agreements, common market and economic union.

Table 22: Numbers of MEAs results

Variable	1	2	3	4	5
Ln GDP reporter	0.885***	0.908***	0.911***	0.911***	0.911***
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Ln GDP partner	0.680***	0.767***	0.764***	0.764***	0.764***
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
FTA dummy	0.136***		0.098***		0.098***
	(0.03)		(0.03)		(0.03)
Log numbers of MEA		-0.077***	-0.075***	-0.075***	-0.075***
		(0.01)	(0.01)	(0.01)	(0.01)
MEA only				-0.098***	
				(0.03)	
Year Fixed Effect	Yes	Yes	Yes	Yes	Yes
R-sqr	0.528	0.530	0.530	0.530	0.530

* $p < 0.05$, ** $p < 0.01$,***$p < 0.001$

Custom unions are likely to increase bilateral trade volume by 0.665, of which the coefficient for common market is 0.404 and 0.419 for economic union. The effects of EIAs are negative and significant except in column 6. After taking bilateral country fixed effects, importer by year and exporter by year fixed effects, almost all variables are insignificant. The coefficient for IEAs dummy is 0.540 and significant at 99% level. This result is quite close to FTA dummy only case since the categorization of trade agreements should have no effects on the coefficient of IEAs. Table 25 lists the results for the numbers of environmental agreements. The negative effects of environmental agreements do not change comparing to the previous parts. 1% increase in numbers of environmental agreements decreases bilateral trade by 7.7%.

Table 23: OLS Regression Results for Different Types of FTAs

Variable	1	2	3	4	5	6	7	8	9
Ln GDP Reporter	0.681***	0.684***	0.683***	0.884***	0.898***	0.898***	0.813***	0.821***	0.822***
	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)	(0.02)	(0.03)	(0.03)	(0.03)
Ln GDP Partner	0.538***	0.549***	0.550***	0.680***	0.699***	0.701***	0.672***	0.685***	0.688***
	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
FTA Type=0	0.055	0.305**	0.333**	0.085	0.347**	0.366**	-0.104	0.075	0.072
	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.13)	(0.13)	(0.13)
FTA Type=1,2,3	0.152	0.388***	0.043	0.230*	0.480***	0.184	0.404**	0.578***	0.240
	(0.11)	(0.12)	(0.20)	(0.11)	(0.12)	(0.20)	(0.13)	(0.13)	(0.20)
FTA Type=4	0.438**	0.665***	1.324***	0.503***	0.744***	1.531***	1.041***	1.211***	2.985***
	(0.14)	(0.14)	(0.29)	(0.14)	(0.14)	(0.29)	(0.15)	(0.15)	(0.32)
FTA Type=5	0.191	0.404**	0.432**	0.163	0.388**		0.210	0.366*	0.359*
	(0.13)	(0.13)	(0.13)	(0.13)	(0.13)		(0.15)	(0.15)	(0.15)
FTA Type=6	0.213	0.419**		0.221	0.441**		0.490**	0.648***	
	(0.16)	(0.16)		(0.16)	(0.16)		(0.18)	(0.18)	
MEA Dummy		-0.544***	-0.545***		-0.577***	-0.570***		-0.394***	-0.360***
		(0.05)	(0.05)		(0.05)	(0.05)		(0.06)	(0.06)
Type 1,2,3 by MEA			0.374*			0.317			0.336*
			(0.18)			(0.18)			(0.16)
Type 4 by MEA			-0.633*			-0.769**			-1.845***
			(0.26)			(0.26)			(0.31)
Country FE	No	No	No	No	No	No	Yes	Yes	Yes
Year FE	No	No	No	Yes	Yes	Yes	No	No	No
R-sqr	0.526	0.527	0.527	0.529	0.530	0.530	0.720	0.720	0.720

* $p < 0.05$, ** $p < 0.01$,*** $p < 0.001$

Table 24: Panel Regression with Fixed Effects for Different Types of FTAs

Variable	1	2	3	4	5	6	7	8
Ln GDP Reporter	0.681***	0.687***	0.684***	0.683***	0.884***	0.895***	0.898***	0.898***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)	(0.02)	(0.02)
Ln GDP Partner	0.538***	0.554***	0.549***	0.550***	0.680***	0.702***	0.699***	0.701***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)	(0.02)	(0.02)
FTA Type=0	0.055		0.305**	0.333**	0.085		0.347**	0.366**
	(0.11)		(0.11)	(0.11)	(0.11)		(0.11)	(0.11)
FTA Type=1,2,3	0.152		0.388***	0.043	0.230*		0.480***	0.184
	(0.11)		(0.12)	(0.20)	(0.11)		(0.12)	(0.20)
FTA Type=4	0.438**		0.665***	1.324***	0.503***		0.744***	1.531***
	(0.14)		(0.14)	(0.29)	(0.14)		(0.14)	(0.29)
FTA Type=5	0.191		0.404**	0.432**	0.163		0.388**	
	(0.13)		(0.13)	(0.13)	(0.13)		(0.13)	
FTA Type=6	0.213		0.419**		0.221		0.441**	
	(0.16)		(0.16)		(0.16)		(0.16)	
MEA Dummy		-0.526***	-0.544***	-0.545***		-0.554***	-0.577***	-0.570***
		(0.05)	(0.05)	(0.05)		(0.05)	(0.05)	(0.05)
Type 1,2,3 by MEA				0.374*				0.317
				(0.18)				(0.18)
Type 4 by MEA				-0.633*				-0.769**
				(0.26)				(0.26)
Year Fixed Effects	No	No	No	No	Yes	Yes	Yes	Yes
R-sqr	0.526	0.527	0.527	0.527	0.529	0.529	0.530	0.530

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

4.5 Conclusion and Future Study

This work attempts to answer the question that whether bilateral/multilateral environmental agreements decreasing international trade flow. Same as evaluating the effects of free trade agreements, estimating the effects of environmental agreements with gravity equation suffer from the bias caused by the endogeneity due to unobserved heterogeneity. We applied various methods, from standard cross-section gravity models with or without adding fixed effects, to fixed effect panel regressions. Our results imply that environmental agreements decrease bilateral trade by 55% to 70%. And this number is much smaller than OLS regression, which means the cross-sectional gravity model overestimates the negative effects of environmental agreements. The bias of OLS regression suggests there is a self-selection bias from engaging in environmental agreements. Countries are more likely to have multilateral environmental agreements when they expect smaller effects on international trade, or comparative advantage. Also, we further study the different types of free trade agreements and their interactions with environmental agreements.

There is much more work to be done in the future. In this chapter we put more weight on considering the presence of environmental agreements rather than the number of them. By using the number of IEAs as independent variables we could obtain more detailed results. Moreover, the types, subjects, coverage, and lineage of environmental agreements may have different effects on international trade. A single dummy variable standing for EIAs provides us with a limited capacity to examine the effects. For instance, agreements on pollution of air and oceans may have larger effect on bilateral trade in energy intensive sectors, while agreements on species and habitats have relatively smaller effects on international competitiveness. Highly aggregate data on either trade volume or numbers of environmental agreements provides limited results.

Additionally, the lineage of environmental agreements may bias the results. The

Table 25: The Effects of Log Number of MEAs: Panel Regressions with Fixed Effects

Variable	1	2	3	4
Ln GDP Reporter	0.908***	0.884***	0.910***	0.910***
	(0.02)	(0.02)	(0.02)	(0.02)
Ln GDP Partner	0.767***	0.680***	0.761***	0.761***
	(0.02)	(0.02)	(0.02)	(0.02)
Log numbers of MEA	-0.077***		-0.076***	-0.076***
	(0.01)		(0.01)	(0.01)
FTA Type=0		0.085	1.123***	1.123***
		(0.11)	(0.20)	(0.20)
FTA Type=1,2,3		0.230*	1.248***	
		(0.11)	(0.20)	
FTA Type=4		0.503***	1.505***	
		(0.14)	(0.22)	
FTA Type=5		0.163	1.105***	
		(0.13)	(0.21)	
FTA Type=6		0.221	1.147***	
		(0.16)	(0.23)	
Type 1,2,3 by MEA				1.248***
				(0.20)
Type 4 by MEA				1.505***
				(0.22)
Type 5 by MEA				1.105***
				(0.21)
Type 6 by MEA				1.147***
				(0.23)
R-sqr	0.530	0.529	0.531	0.531

$^*p < 0.05$, ** $p < 0.01$,$^{***}p < 0.001$

upgrade or amendment of existing agreements may or may not affect firms' behavior, hence the influences on international trade are quite unclear. Moreover, we consider only the volume of trade but ignore the extensive or intensive margins. It is plausible that environmental agreements create some trade and terminate other trade. This topic has political significance in evaluating social welfare rather than the volume of trade. A lot of research focuses on how trade liberalization changes the environment; hence, another way to use this data is to study how the trade flows and FTAs change the numbers of environmental agreements.

Nevertheless, our work provides a result of the average treatment effect of environmental agreements on trade, isolating the effects FTAs and adjusting for possible endogeneity and serves as a starting point for a new research agenda.

CHAPTER V

CONCLUSION AND OUTLOOK

This thesis studies the interaction between environmental agreements and international bilateral trade motivated by the pollution haven hypothesis. The pollution havens hypothesis states that stringent environmental policies may drive the dirty industries to the countries with less stringent regulations. My thesis verifies the pollution haven hypothesis from three different aspects, international trade and foreign direct investment changes caused by the European Union Emission Trading Scheme and the general effects of all types environmental agreements on country level bilateral trade flows.

In the second chapter, I use the cross-section, cross-time bilateral trade flow data to evaluate the EU Emission Trading Scheme effect on international trade with a gravity model based on the pollution haven hypothesis. I find that EU ETS increases imports and decreases exports. Separate regressions imply that the pollution haven is generated with respect to the middle income and upper middle income countries, which is consistent with Environmental Kuznets Curve as well. The member countries which are in the (net) short position do face a deterioration of their comparative advantage. The effect of auctions is not significant due to the small portion of the total allowances. Those results suggest that there is a pollution haven effect caused by EU ETS among EU countries. However, there is no significant evidence on how auctions of allowances affected bilateral flows.

My results suggest that further tightening of the emission cap or increases in the compliance cost to producers (auctioned) could disadvantage regulated countries when it comes to international competition. Pollution haven was generated by EU

ETS, particularly for industries short in allowances. Considering that greenhouse gas is a global pollutant, further sacrificing EU economic benefits may not be an optimal choice. For some industries, such as iron and steel, the total effect of EU ETS is to increase their comparative advantage. Thus, in order to achieve emission goals in the third phase, their allocated allowances could be cut, or auctioned. Also, according to my results, the trade pattern is controllable by varying the freely allocated allowances. But, the effect of auction on international trade is still unclear.

The second chapter builds an FDI and international trade model by taking emissions as an input. It assumes endogenous entry and exit of firms so the firms could react to a new environmental regulation, specifically the EU ETS. This complicated nonlinear model implies that FDI flows depend on international trade flows, domestic price, production, import price, wage and rent. It provides insights for improving further traditional gravity model on studying of FDI flows. Moreover, firm heterogeneity is introduced into the model to further explain firm behavior, especially with respect to the firm entry and exit productivity "cutoff" point. The results also highlight that the way allowances are distributed matters for firm behavior. I use cross-country cross-year unbalanced panel data to evaluate the impact of EU ETS on FDI flows by controlling not only for country, industry and year fixed effects, but also including the relative industry level price index, such as wage, rent, import price and domestic price. The coefficients for all prices support the theoretical model. Also, international trade flows have different effects on FDI flows depending on whether they are intra-EU flows or extra-EU flows. The result shows that EU ETS decreases both inward and outward FDI flows. The decrease of FDI inward flows confirm the pollution haven hypothesis. And the decreases of outward FDI flows follow the theoretical model that domestic firms are driven out of the market.

Chapter IV attempts to answer the question that whether multilateral environmental agreements decrease international trade. Same as evaluating the effects of free trade agreements, estimating the effects of environmental agreements with gravity equation suffer from the bias caused by the endogeneity due to unobserved heterogeneity. We applied various methods, from standard cross-section gravity models with or without adding fixed effects, to fixed effect panel regressions. Our results imply that environmental agreements decrease bilateral trade by 55% to 70%. And this number is much smaller than OLS regression, which means the cross-sectional gravity model overestimates the negative effects of environmental agreements. The bias of OLS regression suggests there is a self-selection bias from engaging in environmental agreements. Countries are more likely to have multilateral environmental agreements when they expect smaller effects on international trade, or comparative advantage. Also, we further study the different types of free trade agreements and their interactions with environmental agreements.

Future work should focus on data modifications. Like other FDI or relocation studies of the pollution havens hypothesis, my work does not find mathematically significant results either. Firm level datasets could also solve a part of the problem since it could capture more detail about firms' reactions in facing a new environmental regulation. However, firm level data could also be problematic because of randomness. Firm's market power could also influence accurate evaluation of environmental regulations. Or other disaggregated data could be helpful. If we can further separate FDI flows into intra-EU FDI flows and extra-EU FDI flows, it could provide us more results about how EU ETS shifts investment.

With our current datasets, there is also much more work to be done in the future. In chapter IV we put more weight on considering the presence of environmental agreements rather than the number of them. By using the number of multilateral environmental agreements as the independent variable we could obtain more detailed results. Moreover, the types, subjects, coverage, and lineage of environmental agreements may have different effects on international trade. A single dummy variable identifying the existence of trade agreements provides us with a limited capacity to examine their effects. For instance, agreements on pollution of air and oceans may have larger effects on bilateral trade in energy intensive sectors, while agreements on species and habitats may have relatively smaller effects on international competitiveness. Highly aggregate data on either trade volume or numbers of environmental agreements provides limited results.

Additionally, the lineage of environmental agreements may bias the results. The upgrade or amendment of existing agreements may or may not affect firms' behavior, hence the effect on international trade are potentially not as clear as one would like. Moreover, we consider only the volume of trade but ignore the extensive or intensive margins. It is plausible that environmental agreements create some trade and terminate other trade. This topic has political significance in evaluating social welfare rather than the volume of trade. A lot of research focuses on how trade liberalization changes the environment; hence, another way to use this data is to study how the trade flows and FTAs change the numbers of environmental agreements.

We can also widen our work by going to more detailed studies on international trade flows. For example, we can study how the extensive margin and intensive margin change before and after an environmental policy launched. Environmental policy may generate bilateral trade for some eco-friendly industries, hybrid automobiles and manufacturing devices, while impeding trade for "dirty" goods. Hence, by examining how extensive margin and intensive margin change could provide us with more clues about the relationship between international trade and multilateral or bilateral environmental agreements.

APPENDIX A

ABBREVIATION

CES: Constant Elasticity of Substitution

CITL: Community International Transaction Log

EEA: European Environmental Agency

EU: European Union

EU: ETS European Union Emission Trading Scheme

EUA: European Union allowances

FDI: Foreign Direct Investment

FE: Fixed Effect

FTA: Free Trade Agreements

GDP: Gross Domestic Production

HMNE: Horizontal Multinational Enterprises

HOV model: Hecksher-Ohilin-Vanek model

IEA: International Environmental Agreements

MEA: Multilateral Environmental Agreements

NAP: National Allocation Plan

OECD: Organisation for Economic Co-operation and Development

PHH: Pollution Haven Hypothesis

SITC: Standard International Trade Classification

TRI: Toxic Release Inventory

UNCHE: United Nations Conference on the Human Environment

UNFCCC: United Nations Framework Convention on Climate Change

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